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UNITED STATES DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

WASHINGTON, D.C.

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CORRECTIONS

MONTHLY WEATHER REVIEW, Volume 59, March, 1931:

Page 98, Table 1, column headed "Caspian Sea," first entry, "High, 1838" should be "High, 1638."

Page 103, Figure 6, bottom line, in the two last squares, "A3=16″=7.74" the "7.74" should be "6.74," and in the next column "6.38" should be "6.08."

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 59, No. 5
W. B. No. 1048

MAY, 1931

CLOSED JULY 3, 1931
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TWO SERIES OF ABNORMAL WINTERS

By THOMAS ARTHUR BLAIR

[Weather Bureau, Lincoln, Nebr., March 11, 1931]

In the middle Missouri Valley and adjacent portions of the Great Plains and of the Mississippi Valley, there was a remarkable series of six consecutive cold winters (December to February, inclusive), from that of 1882–83 to that of 1887–88. In the same region a series of six consecutive warm winters occurred from 1918–19 to 1923–24, inclusive. These persistent tendencies of six years' duration are clearly shown in Figure 1, in which are plotted the accumulated sums of departures of the winter temperatures, for the States of Nebraska and Kansas and for the cities of Des Moines and Huron.

The continuance of such abnormalities through successive winters suggests the persistence of important pressure anomalies. If the average pressure deviations of the six cold winters be entered on one chart, and those of the six warm winters on another, the "accidental" variations of the individual years will be largely eliminated, and the resulting maps should show some of the larger characteristics common to the winters of either series, and perhaps give some additional information about the nature of those pressure oscillations and correlations with which Hildebrandsson, the Lockyers, Walker, and others have dealt so extensively. In Figures 2–9 an attempt has been made to draw such charts for the entire globe and for departures of temperature and precipitation as well as those of pressure. The data were taken from World Weather Records (1). It is recognized that they are very inadequate in many parts of the world, especially for the years after 1920. Many irregularities of the curves are doubtless thus omitted and some large areas perhaps improperly represented, but the main features of the various distributions, especially in the Northern Hemisphere, are unmistakably shown.

Winter-pressure deviations.—Figure 2 shows the departures from normal pressure for the months of December, January, and February for the period of six years, beginning with December, 1882, and ending with February, 1888, here called the cold winters of 1883–1888, and Figure 3 similarly for the warm winters of 1919–1924. A general reversal of pressure departures in roughly latitudinal belts is the most evident feature of these charts. The reversal is practically complete in the Northern Hemisphere but doubtful in the Southern Hemisphere. In the cold winters, a band of subnormal pressure surrounding the globe and centering at about the Tropic of Cancer but with extensions into the southern oceans, separates belts of above normal pressure in higher latitudes, both north and south. In the warm winters the central belt is one of high pressure in about the same latitude with southward extensions over the oceans and there is a complete north polar belt of low pressure. The southern belt of low pressure appears to be incomplete, accepting the positive departure at the South Orkneys, based on a short record, as representative of Antarctic regions.

The charts show a weakening of the tropical high-pressure belt in the Northern Hemisphere in the cold winters, and a strengthening in the warm winters, with corresponding increases and decreases, respectively, of pressure in north polar regions. The well-known contrast between Iceland and the Azores is strongly shown in Figure 3, but is weak in Figure 2. On the other hand

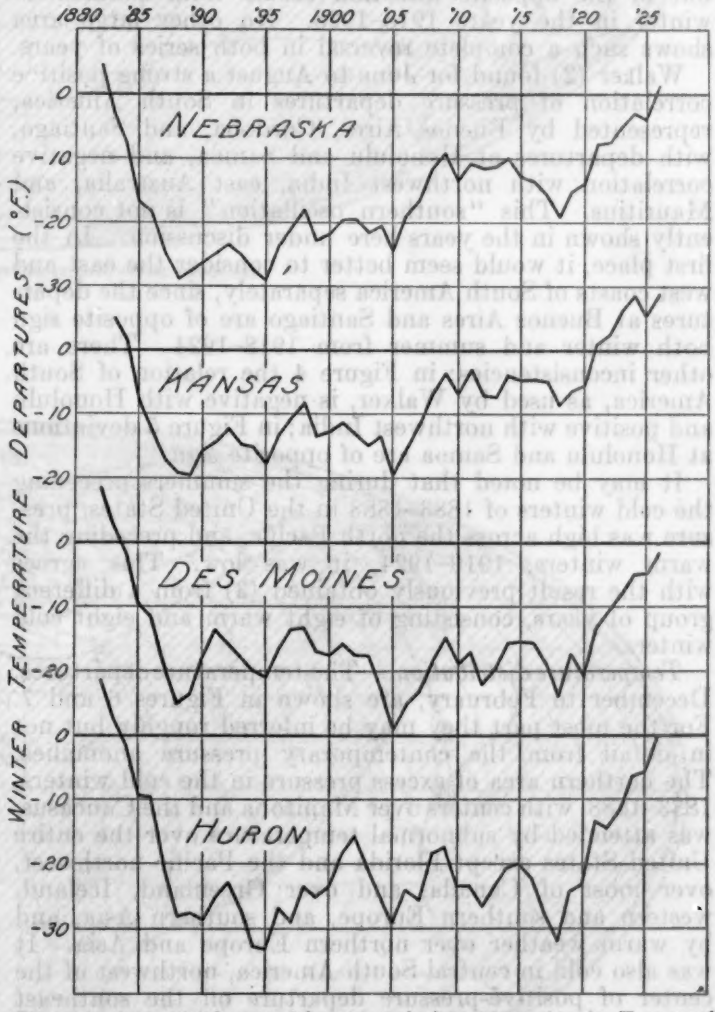

FIGURE 1.—Accumulated sums of departures of winter temperature for Kansas and Nebraska and Des Moines, Iowa, and Huron, S. Dak.

the opposition between Honolulu and Alaska is well developed in the cold winters but not in the warm winters. The departures at Honolulu, northwest India, and south Australia, are of the same sign in each case, as found by Walker (2) for the months of December to February.

Summer-pressure deviations.—In Figures 4 and 5 are represented the average pressure departures six months

earlier each year; that is, for June to August, 1882–1887 and 1918–1923. We see that the pressure distributions of June to August are recognizably related to those of December to February, in the corresponding years. The belts of deficient pressure in Figures 2 and 4 have the same general character, and many of the irregularities of the boundaries maintain their identity, though shifted somewhat in position. For example, the two northward tongues from the southern high-pressure area in Figure 4 persist six months later in Figure 2, and the well-marked deficiency separating them appears in both maps. In Figures 3 and 5 the similarity is less striking, and the central girdle of high pressure has shifted from the Southern Hemisphere in the southern winter to the Northern Hemisphere in the northern winter.

The most notable change from summer to winter is the complete reversal of pressure departures in the north Pacific in both series of years. For June to August, 1882–1887, pressure is above normal in practically the entire Pacific Ocean north of the Equator; six months later it is all below normal. The same complete change but in the opposite direction occurs from summer to winter in the years 1918–1923. No other large area shows such a complete reversal in both series of years.

Walker (**2**) found for June to August a strong positive correlation of pressure departures in South America, represented by Buenos Aires, Cordoba, and Santiago, with departures at Honolulu and Samoa, and negative correlation with northwest India, east Australia, and Mauritius. This "southern oscillation" is not consistently shown in the years here under discussion. In the first place, it would seem better to consider the east and west coasts of South America separately, since the departures at Buenos Aires and Santiago are of opposite sign both winter and summer from 1918–1924. There are other inconsistencies; in Figure 4 the relation of South America, as used by Walker, is negative with Honolulu and positive with northwest India; in Figure 5 deviations at Honolulu and Samoa are of opposite sign.

It may be noted that during the summers preceding the cold winters of 1883–1888 in the United States, pressure was high across the north Pacific, and preceding the warm winters, 1919–1924, it was low. This agrees with the result previously obtained (**3**) from a different group of years, consisting of eight warm and eight cold winters.

Temperature distribution.—The temperature departures, December to February, are shown in Figures 6 and 7. For the most part they may be inferred roughly but not in detail from the contemporary pressure anomalies. The northern area of excess pressure in the cold winters, 1883–1888, with centers over Manitoba and the Caucasus, was attended by subnormal temperature over the entire United States except Florida and the Pacific northwest, over most of Canada, and over Greenland, Iceland, western and southern Europe, and southern Asia, and by warm weather over northern Europe and Asia. It was also cold in central South America, northwest of the center of positive-pressure departure off the southeast coast. From 1919–1924 the winters averaged more than 2° F. warmer than normal in a large part of central North America from St. Louis to Eagle, and in nearly all of Europe, in conformity with the marked deficiency of pressure throughout northern latitudes. The reason for the cold area in the vicinity of Newfoundland is not apparent.

In Figure 7 the remarkable feature is the great preponderance of warm weather over all continental areas except Australia. It appears that a combination of all temperature records obtained would indicate that the world was definitely warmer than normal during this period, made up of the same three months in six successive years. Possibly the result would be different if data were evenly distributed over the entire surface of the globe.

Distribution of precipitation.—The distribution of precipitation in percentages of the normal is shown in Figures 8 and 9. For the most part, areas in which pressure, December to February, was above normal were areas of light contemporary rainfall, and those in which the pressure was below normal had more than average rainfall, but the related areas are far from coinciding exactly. In the United States there appears also a negative correlation between precipitation and temperature in both sets of years. The cold winters were wet and the warm winters were dry except in the southern plains region. It has recently been shown in greater detail (**4**) that this inverse relation prevails over a large part of the United States when all winters with temperature departures of 2° F. or more are considered, but that in other areas, including a portion of the southern plains, the relation is more frequently direct.

Both series of years were abnormally wet in Mexico, showing no relation to shifting pressure belts. Temperate South America shows a reversal of precipitation conditions from one series of years to the other more definite than its pressure changes. In Australia there is negative correlation between temperature and precipitation, as in the United States, and an alternation of conditions between northern and southern portions. From 1883–1888 there were dry and warm summers in the south and wet and cool at Port Darwin; from 1919–1924 it was wet and cool in the south and dry and warm in the north.

General remarks.—The cold years of 1884–1886 are connected by Humphreys (**5**) with the great volcanic eruptions of Krakatao, August 27, 1883, and Tarawera, June 10, 1886. This does not account for the fact that the cold began in the winter of 1882–1883; nor does volcanism account for the persistent warm period.

These warm and cold winters fit fairly well into the theory of the influence of sun-spot numbers upon world temperatures, and the periods are approximately one-half the 11-year sun-spot cycle. There was a maximum of sun spots in January, 1884, in the midst of the cold years but the numbers decreased rapidly in 1886 and 1887, while the temperature deficiencies continued into the spring of 1888. The warm period, 1918–1924, which prevailed in all continents except Australia, was a period of continuously decreasing sun spots, reaching a minimum in January, 1924. There was not, however, a very definite termination of the warm period in the Missouri Valley in 1924. After a slight downward tendency in the winter of 1924–25, the curve again moved rapidly upward. The sun-spot maximum of 1893 was followed by three cold winters as shown in Figure 1, and the minimum of 1913 by two or three warm winters, but in these cases, though the extremes of sun-spot numbers were more pronounced than in 1884 and 1924, the temperature changes in north-central America were neither so marked nor so prolonged.

Whatever the causes may have been, these maps show large areas of reversed pressure anomalies and a definite "change of climate" in one of these sets of years as compared with the other. The pressure deviations were not mere statistical abstractions, but were attended by real and important differences of temperature and precipitation over large areas. At Winnipeg the later series of years averaged 12.7° F. warmer than the earlier and over a large portion of Canada and the northern United States

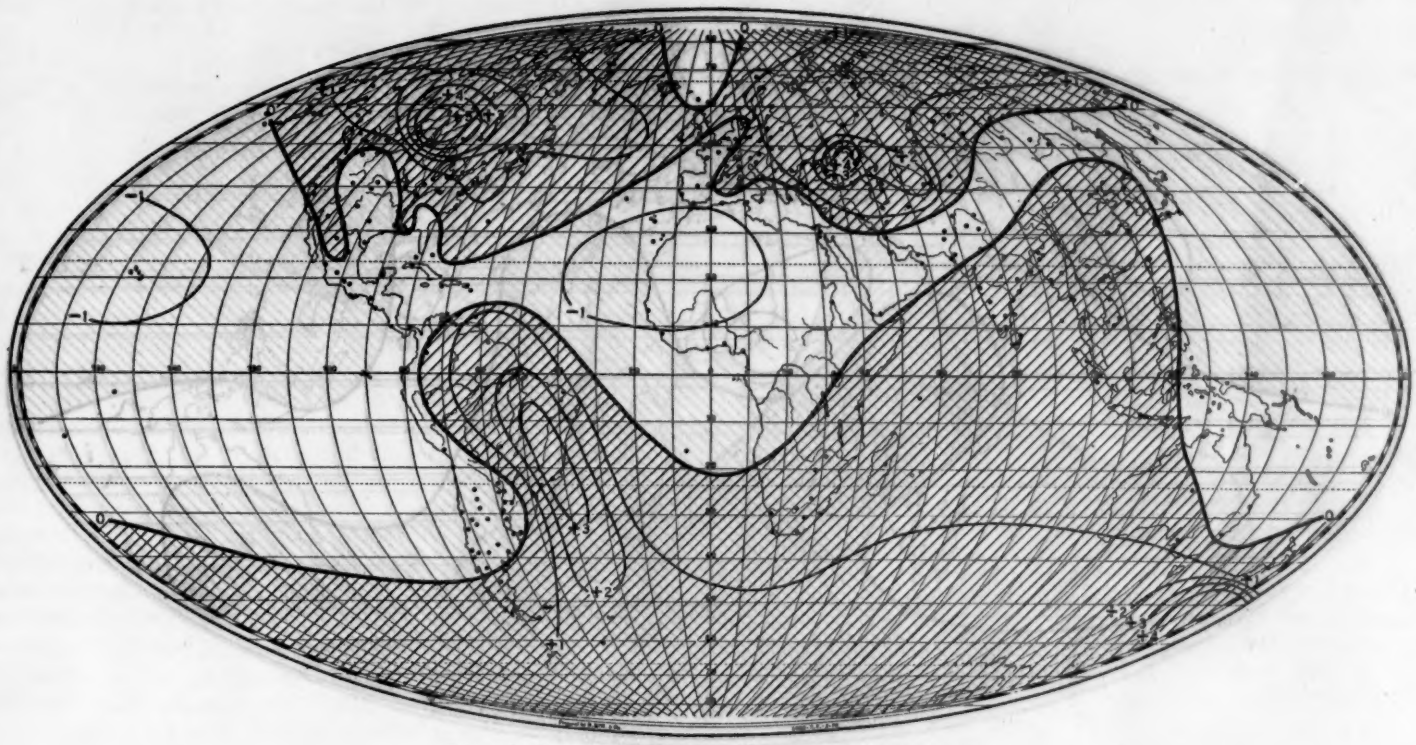

FIGURE 2.—Pressure departures, millibars; cold winters, 1883–1888

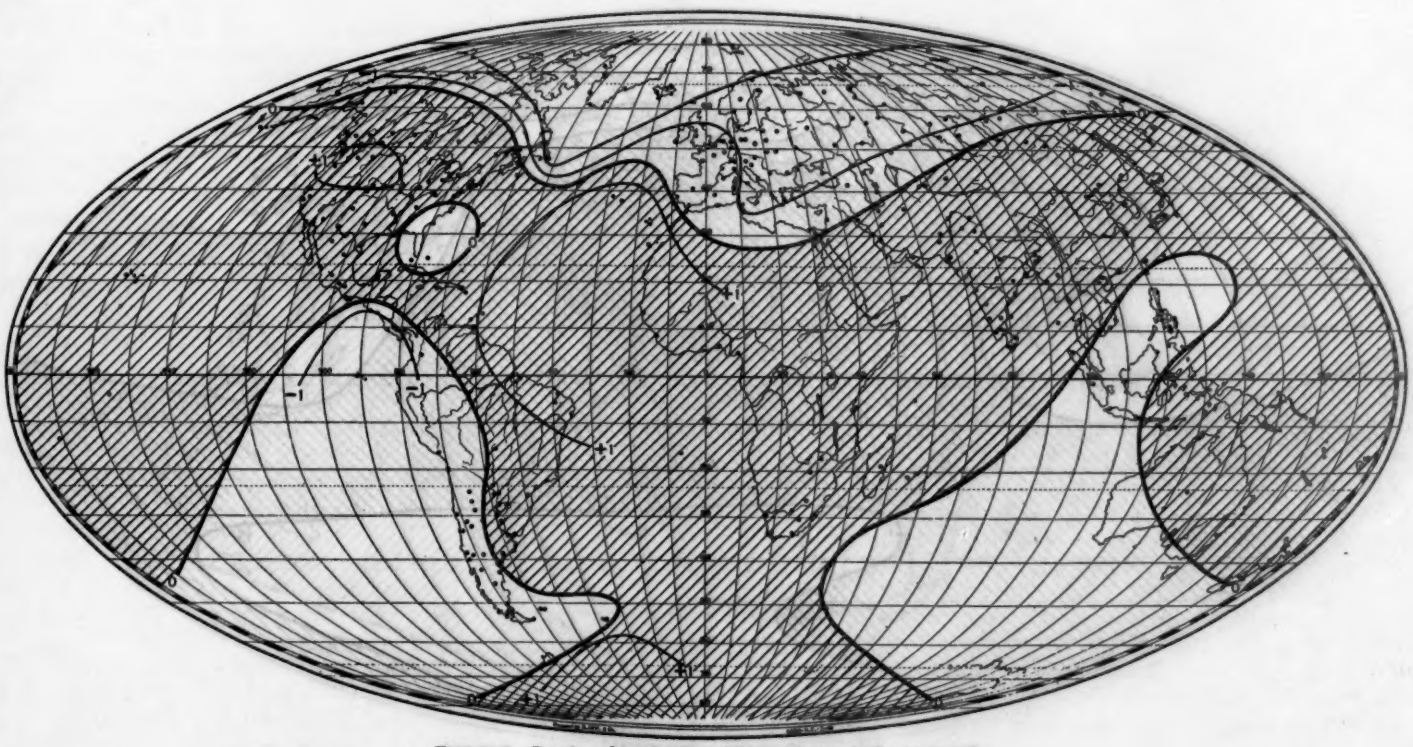

FIGURE 3.—Pressure departures, millibars; warm winters, 1919–1924

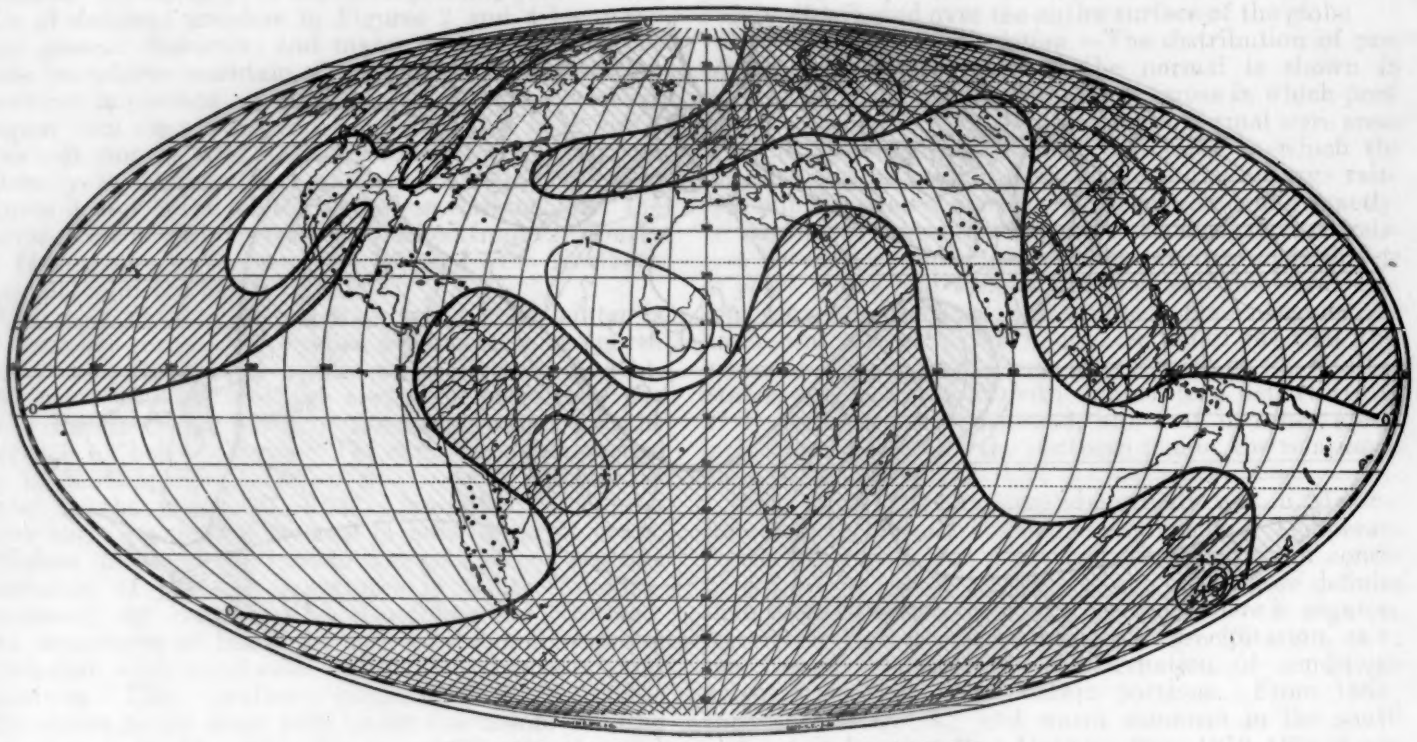

FIGURE 4.—Pressure departures, millibars; June–August, 1882–1887

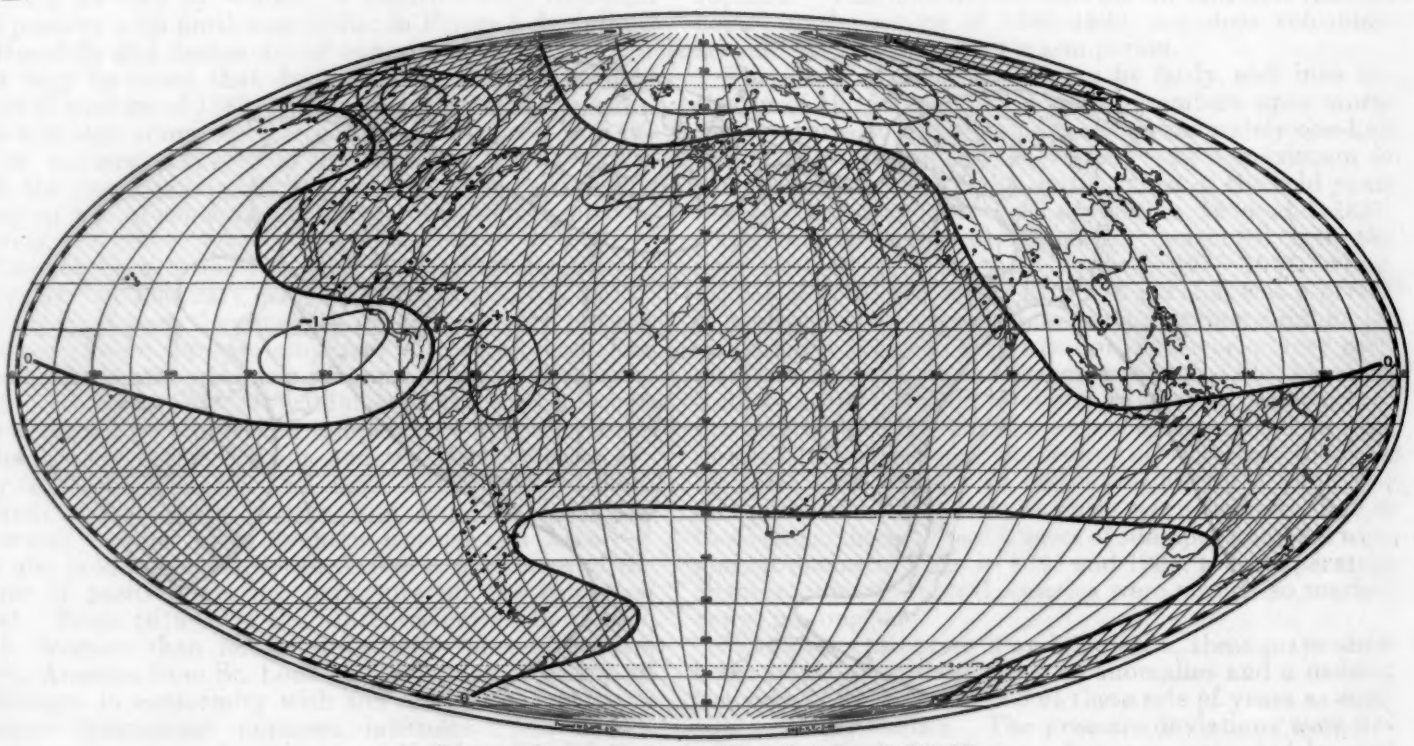

FIGURE 5.—Pressure departures, millibars; June–August, 1918–1923

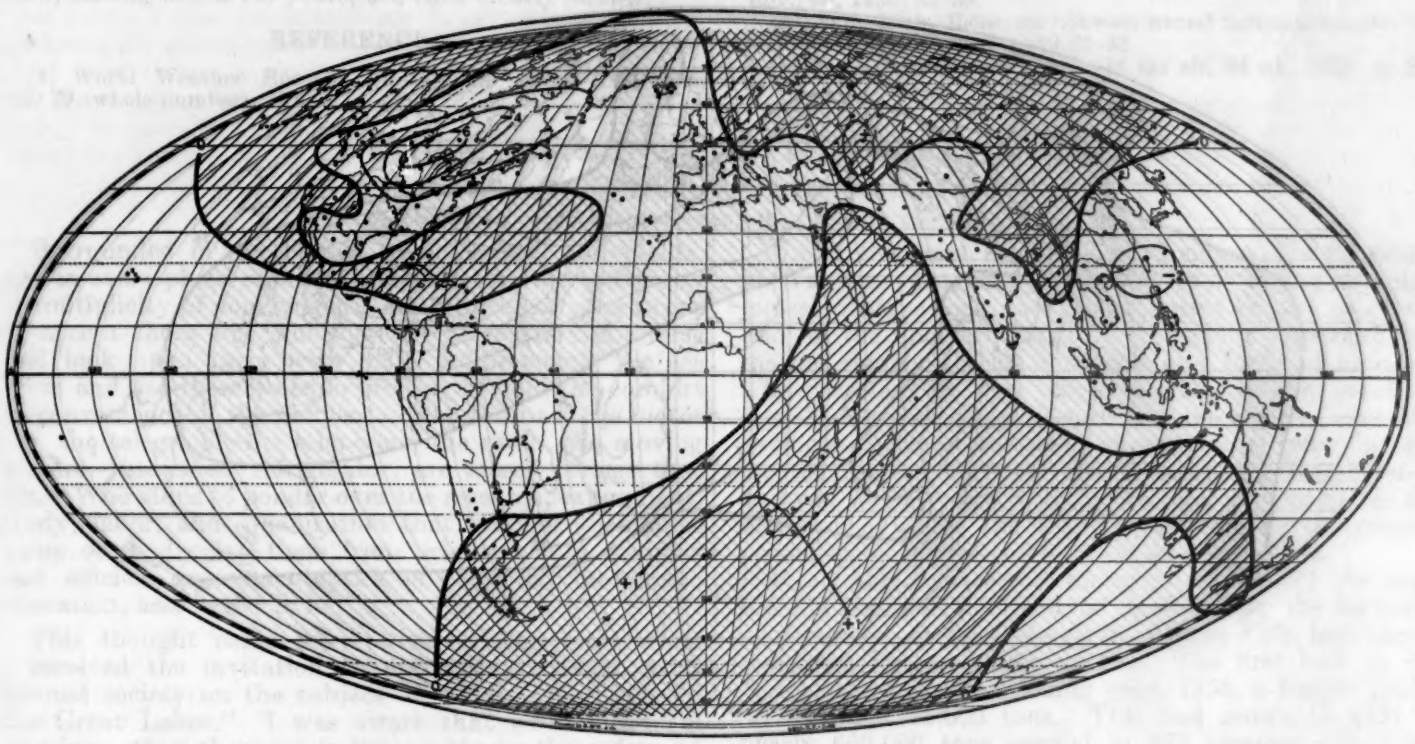

FIGURE 6.—Winter temperature departures; 1883–1888

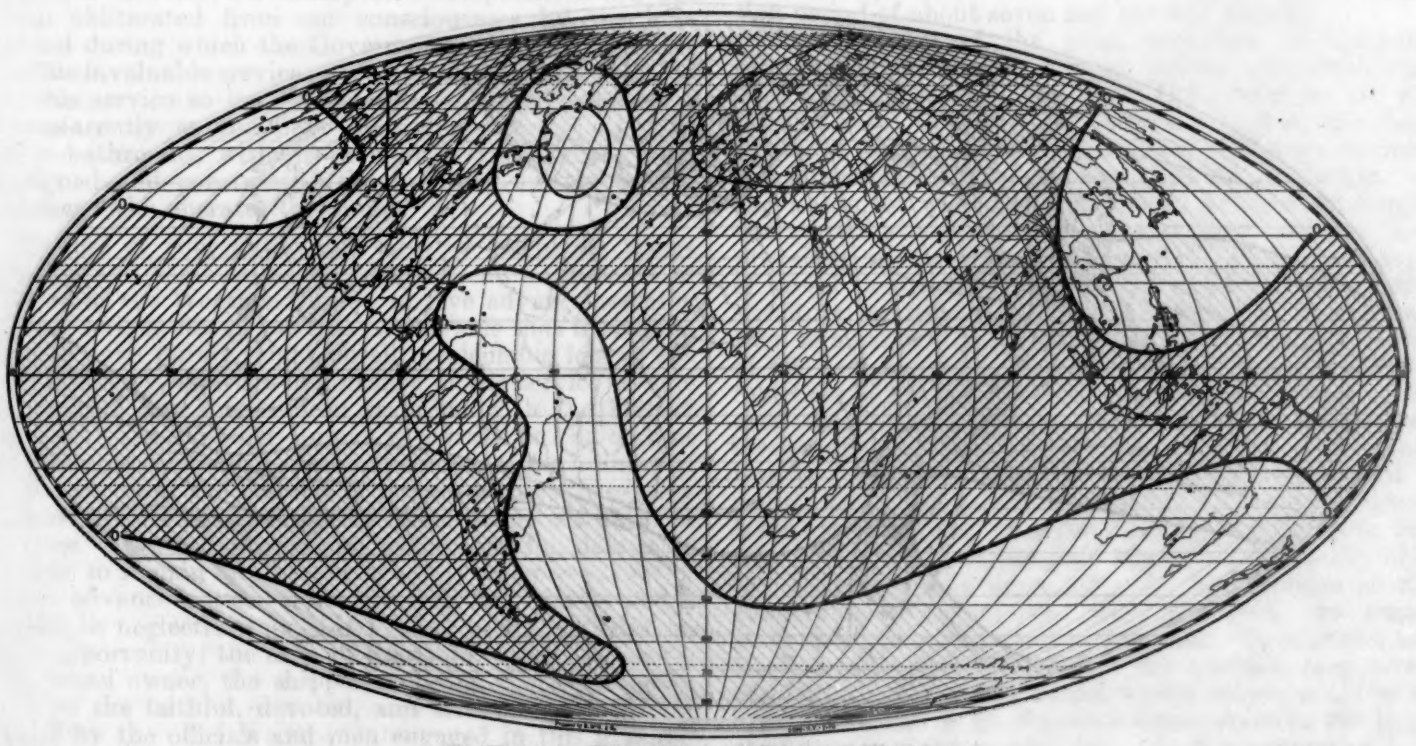

FIGURE 7.—Winter temperature departures; 1919–1924

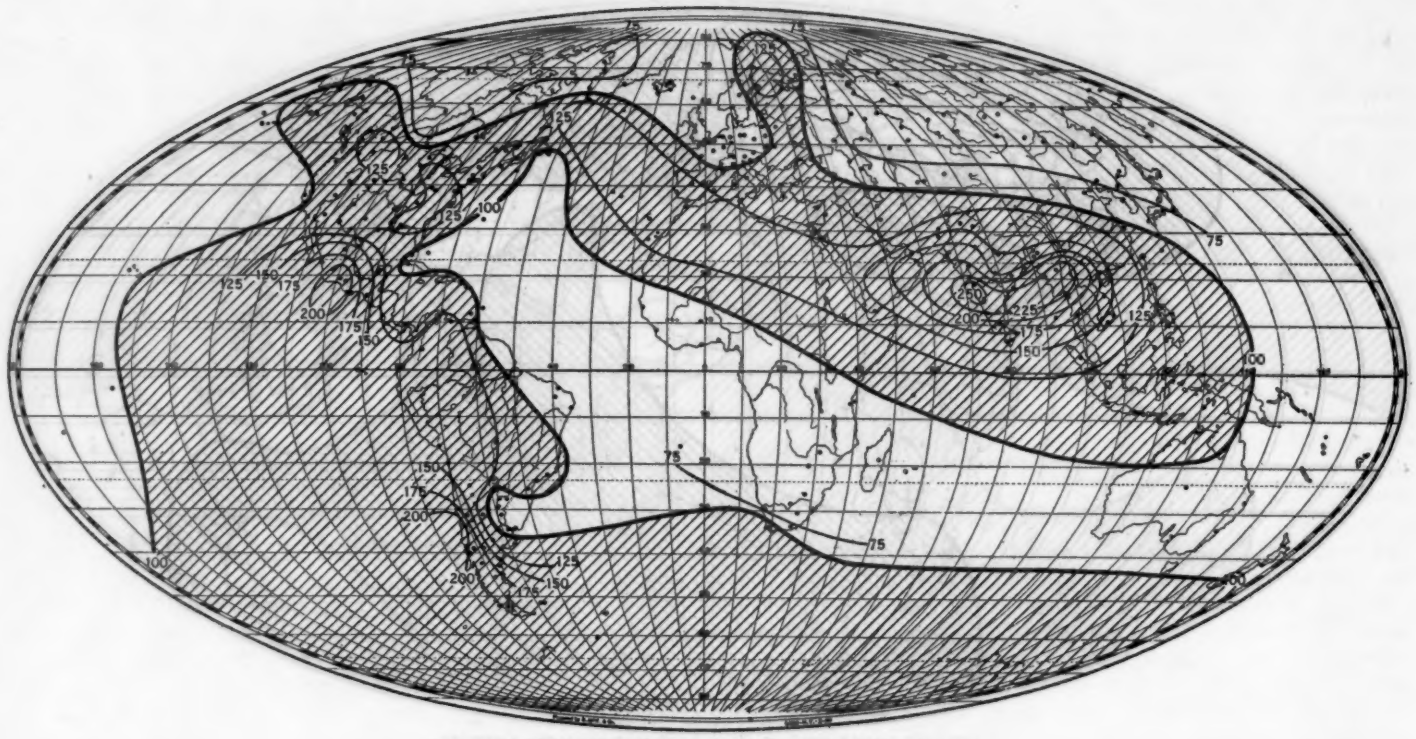

FIGURE 8.—Winter precipitation departures; percentages, 1883–1888

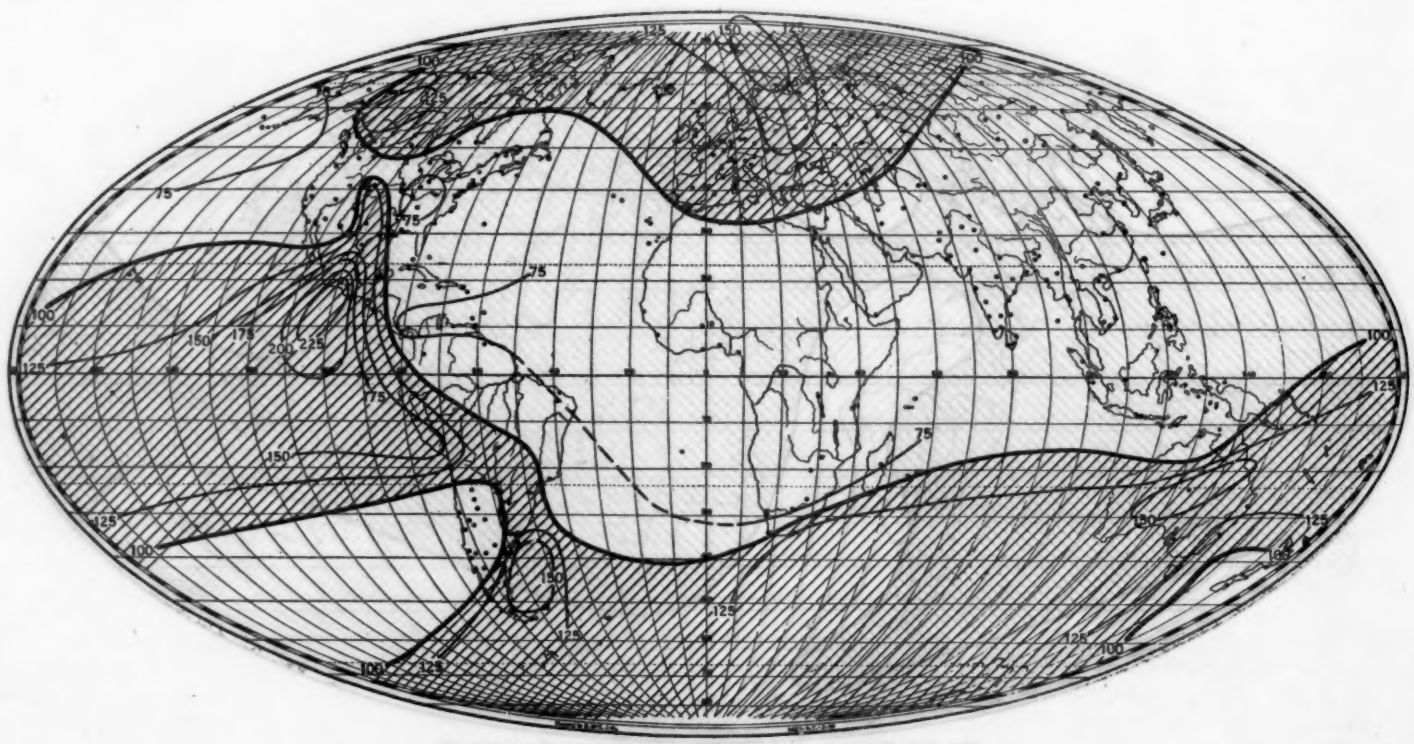

FIGURE 9.—Winter precipitation departures; percentages, 1919–1924

the difference exceeded 4° F. Also, over large areas the precipitation changed from 75 per cent of normal to 125 per cent. Significant changes in the general circulation, lasting about six years, are thus clearly shown.

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(4) T. A. Blair, Relations between winter temperature and precipitation, Mo. Wea. Rev. 59:34–35.
(5) W. J. Humphreys, Physics of the air, 2d ed., 1929; p. 595.

STORM WARNINGS ON THE GREAT LAKES

By GEORGE A. MARR, Vice President, Lake Carriers' Association

[Presented before the American Meteorological Society, Cleveland, Ohio, December 29-30, 1930]

Surrounded in our homes, in our offices and plants, and in every phase of our daily lives, as we are to-day, by a multiplicity of conveniences and utilities, we are prone to accept these aids and comforts as matters of course and look upon them with blasé indifference. We see them and use them with no interest beyond the comfort or convenience of the moment. The railroad, the motor car, the telegraph, the telephone, the radio, the moving picture, the iceless refrigerator, are merely things that *are*. Who stops to ponder over the research, experiment, study, labor, and organization that brought them into being or to develop them from primitive into complex and efficient instrumentalities of pleasure, usefulness, education, and better living?

This thought came home with striking force when I received the invitation to present a paper to your learned society on the subject of "Storm Warnings on the Great Lakes." I was aware that we have storm warnings, that they are indispensable to the safety of navigation, that the mariners place great dependence upon them and that we break into characteristic sailor vernacular if there is suggestion of their discontinuance before the last boat of the season is in winter quarters. And yet they have a history of development which has been obliterated from our consciousness by the long period during which the Government has performed for us this invaluable service. We have enjoyed the benefits of this service so long that we have looked upon it as complacently as you have upon the running water in your bathrooms, without thought of the engineer who designed and constructed the pumping station or the engineer who operates the pumps.

Failure of your automobile or your telephone brings dismay and harsh criticism. I can recall no instance of failure of the Weather Bureau to give advance warning of any serious storm, but it is conceivable that the results of any such failure might entail incalculable loss of life and property, and the importance of the service to safe navigation has always been regarded with the highest esteem. The Weather Bureau is entitled to the highest encomiums. No estimates can be made of the number of lives saved nor the millions of dollars worth of property preserved to transportation by their timely warnings of storms. It is no uncommon occurrence for dozens of vessels to remain in a harbor of safety in consequence of these advance notices from the Weather Bureau and I would be neglectful indeed if I failed to acknowledge, in this opportunity, the debt of gratitude which the sailor, the vessel owner, the shipper, and the traveling public owe to the faithful, devoted, and scientific service rendered by the officials and men engaged in this humanitarian calling.

The Weather Bureau was established by act of Congress in 1890 superseding a similar service inaugurated 20 years before by the War Department under a joint resolution of Congress becoming effective July 1, 1871. Under this joint resolution of Congress, the Secretary of War was charged with the duties of taking meteorological observations and giving notice on the seacoasts and on the northern lakes by "magnetic telegraph and marine signals of the approach and force of storms." The Secretary of War was also authorized to establish signal stations at lighthouses and at such of the life-saving stations on the Lakes or seacoast as were suitably located for the purpose. Lake commerce has therefore enjoyed for 60 years a storm-warning service under the direction of either the War Department or the present organization in the Department of Agriculture.

When this service was inaugurated in 1871 the commercial traffic of the Lakes as measured by the statistics of commerce at the locks of St. Marys Falls had barely outgrown its swaddling clothes. The first lock at the Soo witnessed in its opening year, 1855, a freight traffic of less than 15,000 tons. This had grown in 1871 to nearly 600,000 tons carried in 573 steamer and 1,064 sailing ship cargoes. The commerce of the St. Marys Falls Canals now reaches a total of 100,000,000 tons in approximately 19,000 vessel passages, and the aggregate volume of the freight movement on the Great Lakes is around 150,000,000 tons carried annually in the navigation period of about seven and one-half months.

The adoption of the joint resolution of Congress establishing the storm-warning service was concurrent with the launching of the first bulk freighter on the Great Lakes. The steamer *Robt. J. Hackett*, the forerunner of the present type of ore, coal, and grain carriers, was launched in 1870. She was then the "leviathan" of the Lakes, of wooden construction, 211 feet in length and carried about 1,000 tons at the depth of water then prevailing in the connecting channels. While the type of vessel thus established has remained unchanged, the structural material has changed from wood to iron and then to steel, and the size of ships has grown to a length of 600 feet and over, with a carrying capacity sixteenfold that of the *Hackett*. It may also be interesting to note that at the time the storm-warning service was inaugurated, sailing vessels constituted the major portion of the Great Lakes fleet. To-day there is not a sailing vessel left in the commercial trade of the upper lakes, the last one, *Our Son*, having foundered in the September storm of the past season. Incidentally this ship was built five years after the inauguration of the storm-forecasting service. Such has been the transformation of the lake fleet in 60 years. To a person not familiar with the Great Lakes the question may occur as to whether on these inland waters storms could arise of such force as to be of serious consequence to the large steel vessels of the present day. In this connection it is only necessary to refer to the storm of 1913 in which nine modern steel steamers were sunk without trace, and one, a 10,000-ton vessel loaded with coal, floated, bottom side up, on Lake Huron for several days, a striking manifestation of the power of a lake storm.

That the storm-warning service was undertaken by the Government primarily for the benefit of navigation is evident from the provision of the joint resolution of 1870 which authorized the establishment of marine signal stations, and also from the act of 1891 in which the duties, of the Weather Bureau are enumerated in the following order:

(*a*) Forecasting the weather.
(*b*) Issuance of storm warnings.
(*c*) Display of signals for the benefit of agriculture, commerce, and navigation.

Then follows the enumeration of a half-dozen other duties, but that the giving of warnings to commerce and navigation was the prime purpose of the Government is apparent from precedence given to these services in the language of the act.

It will be noticed that the joint resolution establishing the service under the direction of the Secretary of War required the Secretary to give warning of the approach and force of storms by "magnetic telegraph and marine signals." Since that time there have been remarkable advancements made in means of communication. The "magnetic telegraph" itself has undergone great development, not only by invention and improvement, but by expansion, so that communication by this means is now universal and the wire facilities for making forecasts and broadcasts have been greatly improved. But at best the "magnetic telegraph" affords means of communication only with land stations and with ships that are either in port or passing so closely to port as to be able to see the visual signals of impending storm. Vessels that have passed these sources of information before warnings were issued are at the mercy of the storm until reaching the next shelter, perhaps hundreds of miles distant, after the breaking of the storm.

The most marked, the most important, and I might say, the most dramatic step in the evolution of facilities for communication lies in the invention of the wireless telegraph. Neither the Weather Bureau nor the navigation interests have been slow to recognize the benefits of this and apply them to the paramount purpose of saving life and property at sea. There is rarely a violent storm at sea that does not bring to us through the press stories of ships in distress that have been succored and saved by other vessels which have received through the ether the magic S O S signal. While we of the Great Lakes can not "point with pride" to instances of this character that occur so frequently on salt water, we have nevertheless equipped many of our vessels with radiotelegraph instruments, not only to maintain business contact with the ships' officers but to enable them to receive timely warning of atmospheric disturbances and to seek whatever shelter their location and the force and direction of the storm may dictate.

The means of communicating warnings to the vessels at the present time are—

(1) The display of flag and lantern signals at land stations.
(2) The radiotelegraph broadcast.
(3) Broadcasts from radiotelephone broadcasting stations.

The distribution of storm information by the display of flags by day and lanterns by night is the primitive means of conveying the intelligence to ships' masters, and yet, in spite of the progress made by radio, these flag and lantern signals stand to-day as necessary to the safety of navigation as when they were inaugurated 60 years ago, and any thought of their discontinuance must be abandoned, or at least deferred indefinitely.

There are 115 such stations on the Great Lakes, 82 of which are maintained by our Government and 33 by the Dominion of Canada. These are located at strategic points in the various harbors or at conspicuous places on the banks of the connecting rivers, where vessel officers about to leave shelter may, seeing the warning, come to anchor until danger is past.

The ships of United States and of Canadian registry receive the benefit of the warnings displayed by either country. There are in the commercial trade of the Great Lakes 875 vessels, 581 of which fly the Stars and Stripes and 294 the British jack.

The act of June 24, 1910, amended by the act of July 23, 1912, makes it unlawful for any steamer of the United States or of a foreign country navigating the ocean or Great Lakes and licensed to carry or carrying 50 or more persons, including crew, to leave a port of the United States without radio apparatus of 100 miles radius, excepting as to vessels plying between ports not in excess of 200 miles apart.

Under the provisions of this act none of the lake freight vessels is required to be equipped and only a few of the passenger ships. The lake vessels, however, have been equipped to the extent of 224 out of the 581 American vessels and 84 of the 294 ships of Canadian registry, leaving between five and six hundred vessels that are not equipped to receive advices by wireless telegraph.

For communicating storm warnings to these radiotelegraph equipped vessels broadcasts are sent out at stated hours daily over the entire Great Lakes area. These broadcasts are sent in code from wireless telegraph stations at Duluth, Great Lakes, Chicago, Mackinac Island, Rogers City, Alpena, Cleveland, and Buffalo, giving information as to both prevailing and expected weather conditions, and warnings of storms whenever indicated.

In addition to this, a number of ships equipped with direction finders and a larger but unknown number on which officers or members of the crews have installed private "unofficial" receiving sets for entertainment are able to receive the radiophone broadcasts sent out daily by some 30 broadcasting stations at practically every hour of the day.

Such rapid development has followed in the wake of the invention of radio that the most fanciful dreamer can not envision the progress that is still to be made, and there is a disposition to look forward to the perfection of the radiotelephone, already in probationary service, before assuming the cost of equipping the remaining ships with the existing devices, with the current expense of operation and the probability of early abandonment for the substitution of improved equipment.

A deeply appreciated and highly commended additional service was established last year (1929) in an arrangement made through the Weather Bureau office at Duluth and the R. C. A. radiotelegraph station in that port. Under this arrangement reports are sent to Duluth from vessels on the open lake giving details of weather conditions prevailing in the vicinity of these vessels. This information is transmitted to vessels in port at Duluth and Superior, where weather conditions are often of marked difference in character from those prevalent on the lake. Not infrequently masters, warned of severe weather on Lake Superior and of which there was no indication in port, remained in sehlter until reporting vessels gave indication of moderation. So gratefully was this information received by masters that a similar arrangement was made during the season just closed to

inform masters at Sault Ste. Marie of the weather conditions on the east end of Lake Superior and the north end of Lake Huron.

As previously stated, the lake ships have been equipped far beyond the requirements of law, but the major portion of the commercial fleets of both United States and Canada is still dependent upon the flag and lantern displays. In addition to these unequipped vessels of the larger classes engaged in interlake trade there are numerous small craft, such as fishing vessels and yachts to which the flag and lantern displays are the only available warnings of threatened storm.

I have no hesitancy, therefore, in stating that no thought should be given at the present time to the withdrawal or material contraction of the primitive system of flag and lantern displays. On the contrary, if this service can be expanded to greater usefulness in the saving of life and property the study of the Weather Bureau should be directed to that end. For instance, these signals show merely that a storm may be expected from a certain point of the compass. If a simple revision of the code could be arranged to show the anticipated force of the expected storm, the additional information would be valuable.

I make the further suggestion that the Weather Bureau might render an added service by the forecasting of fluctuations in the lake levels, particularly in the vicinity of the shoal places governing the loading depths of the vessels. Some years ago Mr. Frank Jermin, the meteorologist of the Weather Bureau at Alpena, Mich., made an extensive study of the effects of barometric pressure on the lake levels and the currents created by the transit of the high and low pressure areas from one part of a lake to another. The merits of Mr. Jermin's deductions I am not competent to discuss intelligently with you gentlemen, but I have a distinct recollection that Mr. Jermin said that these water-level fluctuations could be forecast with reasonable accuracy about six hours in advance of their occurrence. If this be true, may I not recommend to my Weather Bureau friends that consideration be given to the issuance of advance information with reference to these fluctuations?

While the poet sings of the "bounding billows" and the "wet sheet and flowing sea," the mariner reads with much greater concern the indications of his barometer and the reports and warning signals of the Weather Bureau. The stories they tell may not be ever new, but the interest holds longer than it does in other Twice-Told Tales.

SIGNIFICANCE OF AIR AND SEA TEMPERATURES OBTAINED ON CRUISE VII OF THE "CARNEGIE"[1]

By KATHARINE B. CLARKE

On the tenth of May, 1928, the nonmagnetic ship, *Carnegie*, sponsored by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, took departure from Newport News on its seventh cruise. It was possible on this cruise to inaugurate a complete meteorological program. From the middle of May, 1928, to the middle of November, 1929, except for days in port, air pressure, temperature and humidity, and sea temperature were recorded continuously and a definite effort was made to obtain as accurate records as possible. These *Carnegie* observations are particularly valuable because in some regions of the Pacific where the *Carnegie* cruised meteorological data of known accuracy are scanty if not altogether lacking.

Of the meteorological results which are now being compiled at the Department of Terrestrial Magnetism, those of sea and air temperature are the most complete and accurate.

A continuous record of sea-water temperatures at a depth of approximately two meters was obtained with a mercury-in-steel bulb-and-capillary type of sea-water thermograph with daily movement. Sheets were changed daily at Greenwich mean noon. Immediately before each change of sheet the temperature of the surface sea water was measured by the bucket method. This consisted in lowering a canvas bucket into the sea about two feet below the surface, quickly hauling this to the deck and measuring the water temperature by immersing a standardized thermometer in the bucket. The temperature so obtained was entered on the thermogram. In areas where the sea-surface temperature was changing rapidly, as in entering port or in calm weather, a mean of several bucket readings was taken.

The thermograms were scaled at every full hour local mean time. The differences between thermograph and bucket readings have been recorded, and these values, used as a correction factor, applied to the hourly thermograph readings to obtain true sea-surface temperatures. Bucket temperatures were higher than thermograph temperatures by 0°.8 C. to 0°.9 C. at lower sea temperatures and by 0°.2 C. to 0°.1 C. at higher sea temperatures. Comparing temperatures so obtained with the sea-surface temperatures measured at the oceanographic stations with standardized reversing thermometers a difference greater than 0°.5 C. never was found and at over half the stations the difference was less than 0°.1 C. Values of corrected sea-surface temperatures range from 6°.4 C, (43°.5 F.), recorded just south of the Aleutian Islands at 12^h July 8, 1929, to 30°.2 C. (86°.4 F.) approaching Pago Pago at 14^h, November 14, 1929.

For obtaining air temperatures several types of apparatus were used. The Hartmann and Braun electric-resistance multithermograph was installed for the purpose of obtaining lapse rates from deck to masthead. Three pairs of wet and dry bulb thermometers were installed at various heights above sea level—one pair in the Stevenson shelter on deck 12 feet (3.6 meters) above sea level, another pair in a ventilated screen just above the crosstrees on the mainmast 72 feet (21.9 meters) above sea level, and a third pair at the masthead on the mainmast 113 feet (34.6 meters) above sea level. These Thermometers were calibrated from time to time with an Assmann aspiration psychrometer.

The usefulness of these Hartmann and Braun records has been lessened because corrections for all the single thermometers can not be obtained. It is evident that the recorded values depend upon the efficiency of ventilation of the screens, which in turn is modified by direction and velocity of the wind. Unfortunately these wind-records were lost in the destruction of the vessel.

An examination of these Hartmann and Braun records has revealed a diurnal variation in the apparent lapse rates between deck and crosstrees (masthead-records were too incomplete for use). This must be due to heating of the deck-thermometer during the daylight hours.

[1] Based on a paper presented before the American Meteorological Society, Washington, May 4, 1931. Also cf. Brooks, Charles F. Meteorological Program of the Seventh cruise of the *Carnegie*, 1928–1929, MONTHLY WEATHER REVIEW, May, 1929, vol. 57, pp. 194–196.

It has been possible to use these Hartmann and Braun records in correcting deck-temperatures for overheating, as will be explained later.

The Negretti-Zambra ventilating recording psychrometer was located in the Stevenson screen on the quarter-deck. The recording wet and dry bulb thermometers of this instrument were calibrated daily at Greenwich mean noon by means of an Assmann sling psychrometer. As soon as the wet and dry bulb temperatures were read off on the Assmann they were entered directly on the Negretti-Zambra thermogram. The Negretti-Zambra traces have been scaled at local mean time and hourly values corrected from Assmann reading have been obtained. From these values tables of hourly air temperature, relative humidity, and vapor pressure have been compiled.

Partly as a contribution to climatology and partly to study the diurnal variation of these elements, mean hourly values for areas have been computed. The areas, twenty-two in all, have been selected to represent regions within which small variations of temperature were found, or regions with like variations, such as the Gulf stream crossing. The periods of observation for the areas vary from 3 to 35 days.

As mentioned previously, an examination revealed a diurnal variation in the apparent lapse-rate between deck and crosstree temperatures recorded by the Hartmann and Braun instrument due undoubtedly to overheating of the deck thermometer during the day. Likewise a diurnal variation in differences of temperature recorded by the Hartmann and Braun dry bulb at the crosstrees and the Negretti-Zambra dry bulb in the deck screen has been discovered. The amplitude of this variation, however, is not as great as that of the differences in the two Hartmann and Braun thermometers presumably because the Negretti-Zambra instrument was better ventilated.

It has seemed justifiable to use these curves of differences for computing a correction to be applied to the daytime hourly mean temperatures by areas recorded by the Negretti-Zambra dry bulb. The curve of differences during daylight hours between Negretti-Zambra dry bulb on deck and Hartmann and Braun dry bulb at the crosstrees (means for areas) has been applied as a correction to the mean values of air temperatures. The result of applying these corrections is shown in Figure 6. (Dashed line represents mean air temperature as read from Negretti-Zambra dry bulb and corrected from Assmann readings. Broken line represents what the mean air temperature would be with a correction of the mean differences between Hartmann and Braun deck and crosstree temperatures applied to the Negretti-Zambra dry-bulb means. Full line represents air temperatures corrected for the mean differences of Hartmann and Braun crosstrees and Negretti-Zambra deck dry-bulb temperatures, which is accepted as the most accurate air temperature which can be obtained from the data available.) There are therefore corrected hourly means of sea-surface temperature and of air temperature for 22 areas.

Next a study of the differences between air and sea temperatures was undertaken. Of the daily means for the entire cruise it was found that in 61.5 per cent of the days the mean sea temperature exceeded mean air temperature. On the other 38.5 per cent of the days mean air temperature exceeded mean sea temperature. However, these daily means of air temperature were not corrected for overheating and are undoubtedly too high for actual air temperatures over the sea. Moreover the investigations were all carried out during a summer season or in the tropics and therefore do not represent true annual averages.

In comparing the mean differences for areas between air and sea temperatures, the mean air temperatures corrected for radiation were used. The difference of sea temperature minus air temperature was never as great as 2°.0 C. In only two areas, crossing the Gulf stream and in the Gulf of Panama, were mean sea temperatures more than 1°.0 C. higher than mean air temperatures. This large difference of 1°.6 C. over the Gulf stream may be attributed to the high water temperatures. A difference of 1°.5 C. between mean air and sea temperatures in the Gulf of Panama may be explained by the fact that during the entire 12 days of this series the wind was consistently from the southwest—from a region in which sea temperatures only a few hundred miles away were as much as 8° lower than in the gulf. Thus air considerably cooler than gulf water temperature was imported.

It is, also, interesting to note that of the means for the areas which include that part of the cruise from Japan to San Francisco, air temperatures appear to be slightly higher on the average than sea temperatures. Differences are small, from 0°.1 C. to 0°.7 C. The winds during this part of the cruise usually had a southerly component.

In one other area, that centered off the coast of Chile approximately on the western edge of the Peruvian current, the mean air temperature was 0°.11 C. higher than the rather low mean sea temperature here.

From the corrected hourly means for areas a study of diurnal variation has been made. From the literature concerning previous investigations of this subject it was expected that the diurnal variation in differences between air and sea temperatures would be small—about 1° C.—and that in general air temperatures would be lower than sea temperatures during the night and would approach and probably exceed sea temperatures during the day. Mean hourly air temperatures for areas corrected for radiation and for nonperiodic change, and mean hourly sea temperatures for areas corrected for nonperiodic change were used. For the areas which include that part of the cruise from Iceland to the Mid-North Atlantic (17° north, 38° west) and from Barbados to Callao none of the 24 mean hourly air temperatures exceeded the mean hourly sea temperatures. For all other areas the mean hourly air temperature at some time during the day rose higher than the mean sea temperature. However, when air temperatures not corrected for radiation were used in this comparison, for every area except that of the Gulf stream and of the Gulf of Panama air temperatures exceeded sea temperatures sometime during the day. This seems to indicate that if the effect of radiation could be entirely eliminated the mean daily air temperature would seldom exceed mean daily sea temperature.

It was noted that in some of the areas the air temperature exceeded the sea temperature only during the hours between 8 and 10 a. m. In others the air temperature rose above sea temperature about 8 or 9 a. m. and remained above until late afternoon (see fig. 7). A study for the cause of this revealed that in the areas which had an air temperature greater than sea temperature in the morning and then fell below the rest of the day, that the air temperature was at a maximum about 10 a. m. The most plausible explanation for this seemed to be found in the cloudiness records from the log extract and from some atmospheric-electric observations, which indicated that days included in means which had an early maximum were also days when the sky clouded over in the late morning and remained cloudy the rest of the day, thus producing an effect comparable to that of a mountain climate in summer.

(To face p. 184)

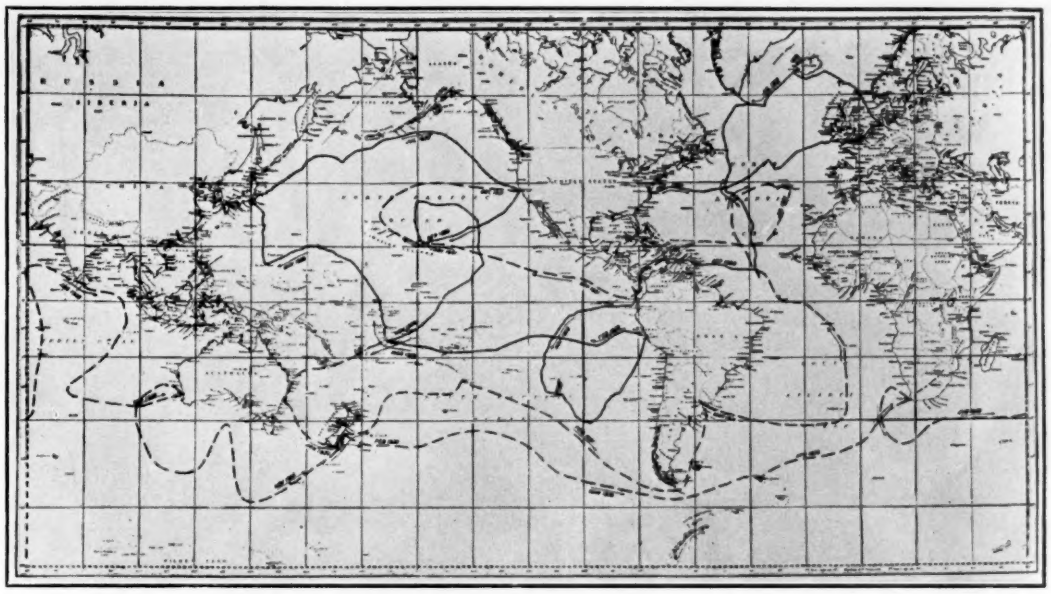

FIGURE 1.—Cruise VII of the *Carnegie*, May, 1928, to November, 1929 (broken line shows portion not completed)

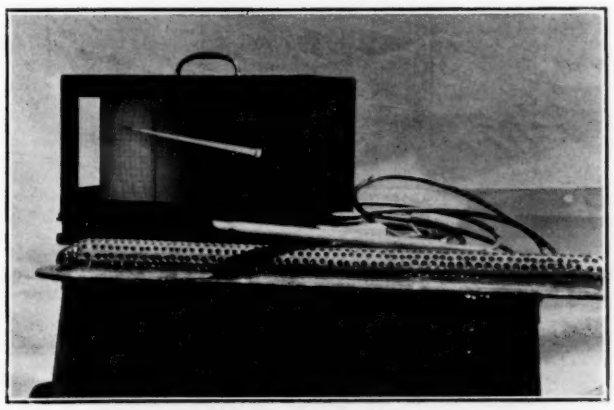

FIGURE 2.—Sea-water thermograph used on *Carnegie*, showing mercury bulb, metal shield, and recording mechanism

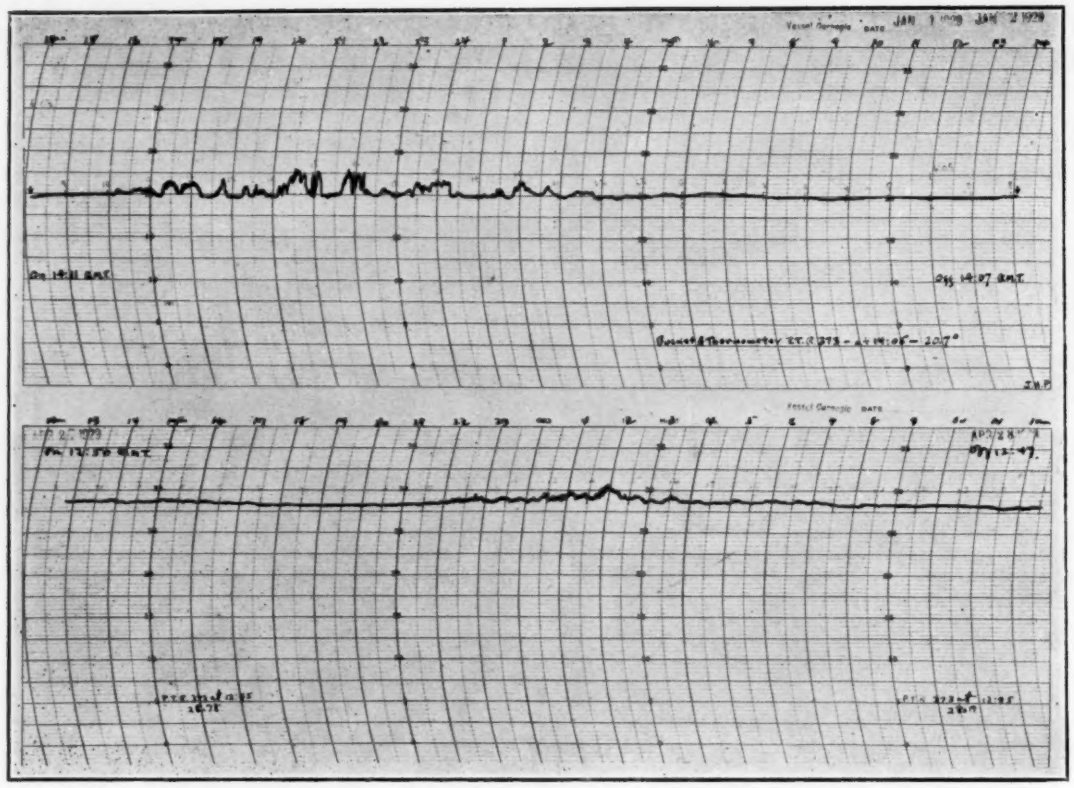

FIGURE 3.—Two thermograms from cruise VII of the *Carnegie* (upper one was obtained on the western edge of the Humboldt Current; lower one is typical of those recorded on calm days in the Tropics)

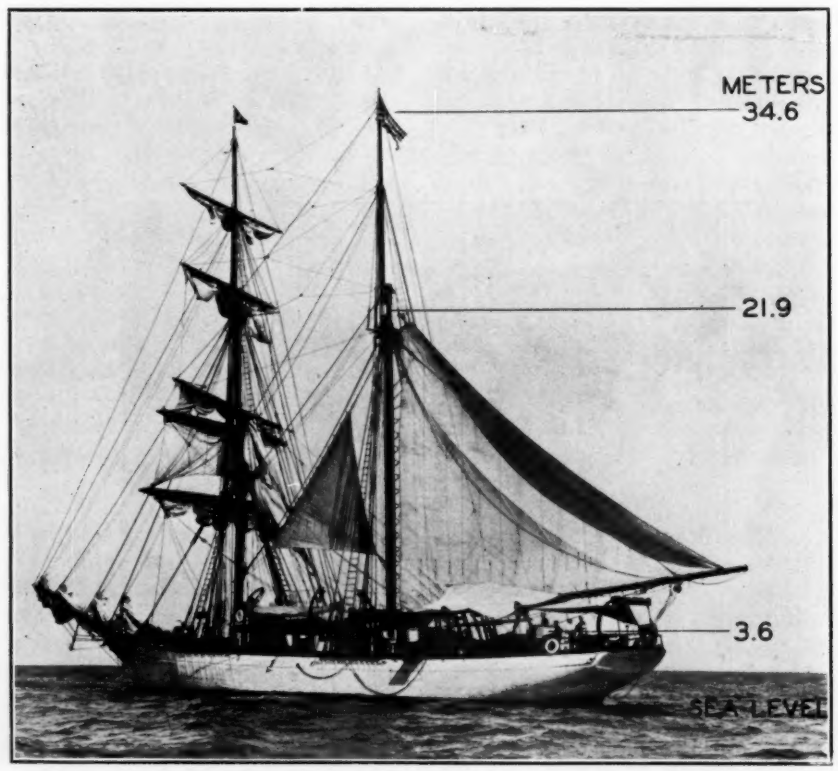

FIGURE 4.—The *Carnegie* showing positions of Hartmann & Braun wet and dry bulb thermometers

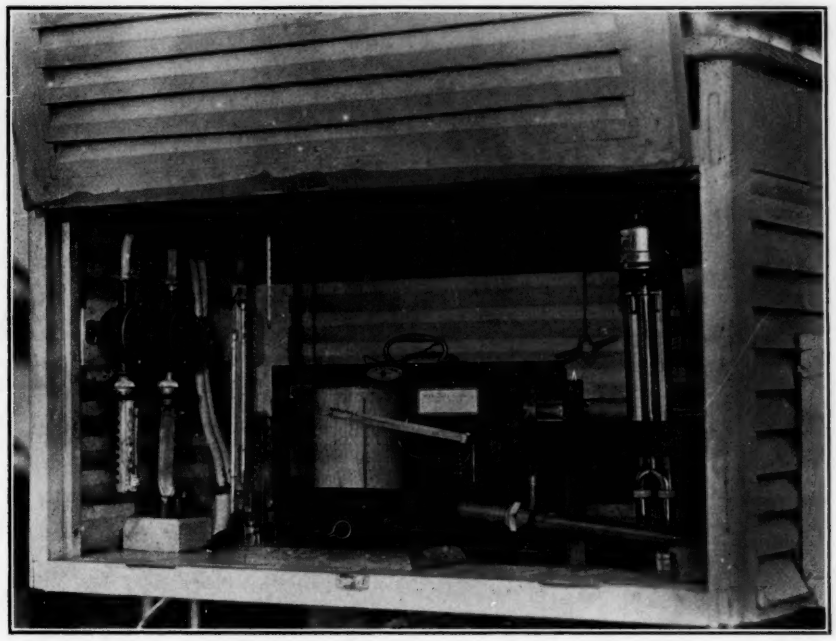

FIGURE 5.—Stevenson screen, open (on left a pair of wet and dry bulb Hartmann & Braun thermometers; in center, Negretti-Zambra ventilating recording psychrometer motor-box outside shelter; Assmann aspiration psychrometer at extreme right)

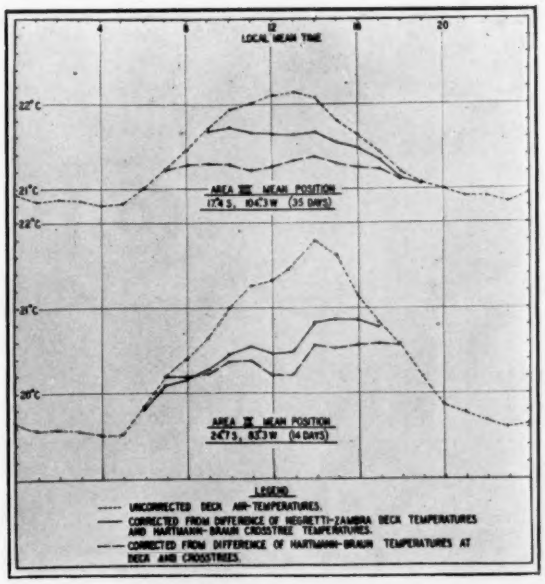

FIGURE 6.—Showing result of correcting excessive daytime temperatures recorded on deck, by means of the diurnal variation in differences between temperatures at deck and crosstree

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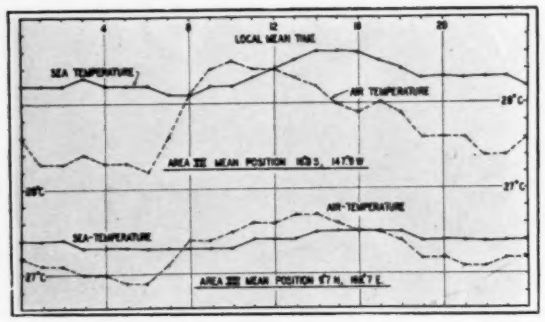

FIGURE 7.—Typical diurnal curves of air and sea temperatures

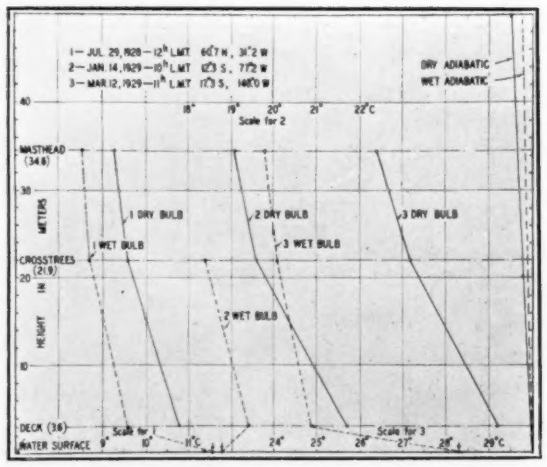

FIGURE 8.—Wet and dry bulb lapse rates

In order to determine to what degree lapse rates obtained by means of thermometers at different heights above deck are useful, the wet and dry bulb temperature at different heights on days when an Assmann calibration with the Hartmann and Braun thermometers was made, were plotted. These daytime lapse rates are shown in Figure 8. The most striking fact is that these rates are decidedly superadiabatic.

(1) July 29, 1928, at 12h local mean time, off coast of Iceland: The dry bulb at the masthead was 1°.5 C. lower than the deck dry bulb, a lapse equal to four times the dry adiabatic. The wet bulb lapse was 1°.1 C. between deck and masthead or six times the saturated adiabatic. The weather was cloudy with a moderate NW. breeze, sea moderate with surface temperature of 11°.6 C.

2) January 14, 1929, at 10h local mean time, entering the port of Callao: There was a dry bulb temperature lapse of 2°.1 C. from deck to crosstrees and of 0°.5 C. from crosstrees to masthead, a total lapse of 2°.6 C. in 35 meters or seven times the dry adiabatic. The wet bulb lapse rate was 1°.0 C. between deck and crosstrees or nine times the saturated adiabatic. Wind was SSE., force 3, weather cloudy, sea temperature 18°.8 C.

(3) March 12, 1929, at 11h local mean time, approaching the island of Tahiti: The dry bulb lapse rate was 2°.0 C. from deck to crosstrees and 0°.8 C. from crosstrees to masthead, a total of 2°.8 C. or seven times the dry adiabatic. Wet bulb lapse was 1°.1 C. in 35 meters or six times the saturated adiabatic. Weather was squally with gentle NW. breeze. Sea-surface temperature was 28°.3 C.

If the deck readings are ignored the lapse rates between crosstees and masthead are respectively two, four, and six times the dry adiabatic. These are exceedingly steep, suggesting that even the crosstree temperatures may have been affected by radiation from deck, sails, and shelter. It is entirely possible that such lapse rates could exist—rates as high as ten or twenty times the dry adiabatic have been observed. Certainly these excessive lapse rates do not represent actual air conditions over the entire ocean for any length of time. It would seem impossible for such unstable conditions to exist throughout a layer of air 35 meters thick for any length of time over any great area.

The results of the study of air and sea temperatures obtained on the *Carnegie* indicate that it is possible to obtain entirely satisfactory sea-surface temperatures with the sea thermograph corrected by careful bucket readings. It seems very probable, however, that air temperatures obtained on a ship at sea, particularly in the summer or in the tropics are too high and do not represent actual conditions over the sea. Since differences between sea and air temperatures are usually less than 1° C., for purposes of studying the physical processes of the atmosphere it becomes necessary to have air temperatures accurate to a tenth of a degree. In order to obtain temperatures of such degree of accuracy methods must be devised for obtaining these continuous temperatures free from the effect of local heating. *Carnegie* data indicate that if air temperatures a few meters above the sea, free from the effects of insolation on the shelter, radiation and heated air could be obtained, it would be found that even the mean hourly air temperatures seldom exceed the sea temperatures. Certainly the sea experts a powerful temperature influence upon the atmosphere.

THE SELECTED-SHIP PROGRAM FOR OCEAN-WEATHER REPORTING BY RADIO

By EDGAR B. CALVERT, Chief, Forecast Division.

[Weather Bureau, Washington]

During the past two years the Weather Bureau has been actively engaged in furthering its share of a project, international in scope, intended to coordinate and improve the work of reporting meteorological conditions at sea by radio. It is not intended that the new scheme, so far as the bureau's own service is concerned, shall supersede the existing arrangement through which it secures by radio, chiefly for its own purpose, a considerable daily collection of reports from ships in the Pacific Ocean and during the hurricane season from ships in the South Atlantic, Gulf of Mexico, and Caribbean Sea. Though the new project is distinctively international in character and is the Weather Bureau's contribution to a world-wide program, it will serve to strengthen materially its own radio weather service from ships at sea.

Weather reports from ships have long been used in advancing knowledge of ocean meteorology and in supplying information concerning storms and other atmospheric conditions over the oceans for the benefit of navigation. In the last quarter of a century ships' weather reports have been collected by radio in increasing numbers, thereby enabling meteorological services to extend daily synoptic charts over the oceans and provide daily forecasts and warnings and synoptic weather information by radiobroadcast for use of ships at sea.

HISTORICAL

A majority of ocean-going vessels traverse waters from which weather reports are needed by the meteorological services of two or more nations. To make weather reports from a ship available to more than one meteorological service, a system of international exchanges must be set up or officers of ships are charged with much additional work in taking observations and forwarding reports to each service separately.

The need of coordination has long been recognized. More than 50 years before the invention of wireless communication, Lieutenant Maury sought more effective cooperation in ocean meteorological work. He attended the First Meteorological Congress in Brussels in 1853, and advocated the establishment of a uniform mode of making nautical and meteorological observations on board vessels of war. The result was that this conference undertook to use a uniform system of meteorological observations both on land and sea all over the world. High honors were bestowed on Maury both in this and other countries because of his work in the fields of oceanography and meteorology, but many may not remember that in 1868, he was appointed professor of meteorology in the Virginia Military Institute at Lexington, which possibly was the first recognition in this way of the science of meteorology by any institution of learning.

Development of wireless communication early in the present century brought many serious complications that did not enter into the program conceived by Maury.

The first wireless message received by the Weather Bureau containing a weather observation from a ship at sea was in December, 1905. Radio weather service from ships at sea was thereafter extended by the Weather Bureau and the weather services of other countries, keep-

ing pace with the installation of radio apparatus on ships. Such reports are now being received by the Weather Bureau at a rate in excess of 50,000 a year.

In order that a weather observation by radio may be promptly handled, a code is necessary. A coded message is much shorter, more economical in communication costs, can be transmitted with greater speed, and is handled more effectively in charting and rebroadcasting. Many different codes came into use, each meteorological service requesting information suited to its particular needs and utilizing a code best adapted to its own requirements.

Another difficulty was that each national weather service desired observations taken at hours most favorable for its daily routine of charting reports and issuing forecasts and information. The result was that officers of a ship traversing extensive oceanic areas were called upon to take observations at various hours, to forward reports by radio in different codes, and to record the observations on forms devised by each service, no two exactly alike.

The collection of ship reports and rebroadcasting of them for the benefit of marine and other interests, as well as international exchanges of reports by radio, were greatly complicated by the diversity of codes in use.

Early in the year 1928, Charles F. Marvin, chief of bureau, and Edgar B. Calvert, chief of the forecast division, representing the Weather Bureau, participated in conferences held in Paris and London for the purpose of working out a more definite and effective program of cooperation. The meetings were attended by officials of the meteorological services of the principal maritime nations of Europe. An agreement was reached whereby each country will arrange to engage a certain number of ships of its own registry on which observations will be taken daily at fixed hours and transmitted by radio. Ships are to be selected from those equipped with standard meteorological instruments and long-range radio apparatus. The number of ships of each nation engaged in the project will be in proportion to that nation's total tonnage of vessels over 100 tons. This program was adopted by the International Meteorological Organization in a conference at Copenhagen in September, 1929,at which Mr. Calvert was the Weather Bureau's representative.

Under the selected-ship plan there will eventually be 1,000 selected ships of all nations sending radio reports regularly during voyages at sea. Of this number about 225 will be of United States registry. These ships are specially selected from those having standard meterological instruments, long-range radio apparatus, and plying routes that are calculated to yield a satisfactory daily distribution of reports from the oceans.

The hours of observation of all selected ships will be identical in all parts of the world—midnight, 6 a. m., noon, and 6 p. m., Greenwich mean time, a latitude of one hour either way being allowed to meet exceptional conditions. Ships having enough watch officers may forward all four observations daily, but on most vessels only two will be radioed, giving preference to midnight and noon, Greenwich mean time.

Ship reports received at certain designated shore radio stations are exchanged by means of collective broadcasts of land and ocean reports in accordance with standard schedules. Meteorological reports are thus made available for mapping and forecasting purposes in many parts of the world within a short time after the observations are taken.

One of the most important features of the plan is that all ships' weather reports will be radioed in the same code, regardless of the nationality of the vessel sending the report or of the meteorological service to which the report is addressed. The essential portion of this standard international code, in groups of figures, with five figures in each group, is universal and invariable but each meteorological service has the choice of additional standardized groups to suit its peculiar requirements. The difficulty in securing adoption of a standard code acceptable to all meteorological services was one of the most serious obstacles in the way of coordination.

The scheme provides that selected ships of United States registry will send reports through foreign radio stations to European services when in the eastern Atlantic and selected ships of foreign registry will send reports to the Weather Bureau through United States coastal stations when in the western Atlantic. A vexing and difficult problem in the international program which concerned the payment of ship to shore tolls on these weather messages has been solved by the generous cooperation of the Radio Marine Corporation and the Mackay Telegraph & Radio Co., in the waiving of ship to shore tolls, regardless of whether the messages are transmitted to United States or foreign shore stations.

PROGRESS

Under an initial appropriation made specifically for the purpose, the Weather Bureau began in 1929 to engage ships in its North Atlantic selected-ship service. The number of United States ships so engaged is now 30. A code book for United States selected ships containing the new international code was issued in May, 1930. The work is done on a cooperative basis and the service is maintained in an efficient manner by frequent personal visits to the ships when in port by Weather Bureau representatives specifically assigned to that duty and by written acknowledgments of service performed. Similar progress has been made by other national meteorological services and radio reports from selected ships of other nations are now being received daily by the Weather Bureau.

Arrangements for international exchanges of ships' weather reports are being perfected. The Weather Bureau transmits twice daily in a radio bulletin for the benefit of European meteorological services, about 100 land station reports representative of weather conditions in the United States, Canada, Alaska, and the West Indies, and a selection of reports from ships in the North Atlantic and Pacific Oceans, the Gulf of Mexico, and the Caribbean Sea. The British Meteorological Service has recently begun transmission to the Weather Bureau of twice-daily bulletins of a similar character containing ship reports as well as observations from representative European land stations to the Weather Bureau. All these broadcasts are now in general conformance with the international codes adopted in Copenhagen in 1929.

Supplemental appropriations have been secured for extension of the selected-ship service to the South Atlantic, Gulf, and Caribbean waters during the fiscal year beginning July 1, 1931. By this means, daily reports from ships in southern waters will be received by radio throughout the year, whereas in the past such observations for the most part have been forwarded by radio only during the hurricane season. It is hoped that appropriations will become available in future years for similar service in the Pacific.

THE RADIATION CONFERENCE AT BERLIN AND POTSDAM,[1] FEBRUARY 23–26, 1931

By H. H. KIMBALL

[Weather Bureau, Washington, D. C., April 30, 1931]

Minutes of the first three sessions have been abstracted by H. H. Kimball from a manuscript furnished by A. Ångström, R. Süring, and K. Büttner. Minutes of the last two sessions have been translated by W. W. Reed.

The first session of the conference was held in the meteorological observatory at Potsdam, on February 23. The following were present: A. Ångström, Sweden; W. Mörikofer, Switzerland; F. Albrecht, K. Büttner, P. Dubois, G. Falckenberg, K. Fuessner, H. von Ficker, W. Kühl, F. Linke, W. Marten, and R. Süring, Germany. At later sessions, T. Burgeron, K. Kähler, A. Defant, H. Hergesell, C. Müller, F. Schmidt-Ott, and K. Stuchtey were also present.

Dr. Ångström opened the session with remarks relative to the objects of the conference, and stated the reasons for giving atmospheric turbidity such a prominent place on the program. He then presented Dr. Süring as presiding officer during the session.

Professor Linke found himself in accord with Ångström in questioning Fowle's determinations of the scattering of solar radiation by aqueous vapor in the atmosphere. He held that the vital point of the discussion is whether the amount of turbidity shall appear as a factor ($I=I_o e^{-aTm}$) or as an additive term ($I=I_o e^{-am-\beta m}$). He also pointed out that the turbidity must be capable of easy and accurate determination, and be independent of the air mass.

Ångström considered it advantageous not to include atmospheric absorption in the measurement of turbidity. Also, in agreement with Büttner, the dependence of turbidity upon wave length is recognized. Therefore, he recommends that the definition of turbidity be in such form that the reduction to a known wave length is easily accomplished. The turbidity coefficient, β, fulfills these conditions, and under mean conditions is independent of the wave length. The dependence of the total turbidity extinction on the wave length is expressed by the exponent a in the term $\frac{\beta}{\lambda^a}$.

At the second session of the commission Linke, Dubois, and Fuessner again discussed the dependence of turbidity on the wave length, and Ångström emphasized the fact that by the use of suitable measurements and computations the turbidity factor, the total turbidity extinction, and also the amount of precipitable water above the station can be determined. A discussion on the use of Schott glass filters in actinometric measurements followed.

The third session met at 10:30 a. m. of February 24 in the room of the "Notgemeinshaft der Deutschen Wissenshaft" in Berlin. Professor Süring proposed that the morning session be given up to a discussion of the question "What apparatus or what method should one recommend for the polar year?" Emphasis was laid on the importance of measurements of the intensity of solar radiation with the sun at different heights, using radiation filters controlled by the Potsdam observatory, so as to insure uniformity of results at different stations. Ångström pointed out the importance of reducing the angular opening of the pyrheliometer to about 5°, or at least all observers should give accurate information on the size of the opening of their pyrheliometer. Upsala, Washington, and Potsdam were designated as points at which pyrheliometers might be standardized in known pyrheliometric units.

In the afternoon a new absolute pyrheliometer was inspected at the Physikalisch-Technischen Reichanstalt, at Charlottenburg.

Fourth session, Wednesay, February 25, 10:45 a. m. at the meteorological observatory, Potsdam.

The following subjects were discussed:

1. Discussion of the term air mass. By air mass there can be designated either the true air mass

$$m_b=\frac{b}{760}\cdot \text{sec. } z, \text{ or sec. } z.$$

In this sec. z is to be taken as the symbol for the Bemporad function. Both measures have their advantages. A decision (between the two definitions) was not reached.

2. After a review of all the σ determinations, the value $\sigma=8.26\cdot 10^{-11}$ was designated as the most probable, since both the most recent measurements as well as the theoretical calculations give this value.

3. Report of Doctor Bergeron, of Oslo, on the eye observations of the opalescent turbidity in the service of synoptics.

The following proposals were formulated for presentation to the international meteorological organization;

1. The measurements of direct solar radiation are to be organized in such manner that in addition to the total depletion of the atmosphere there can be calculated from them the turbidity free from selective absorption by water vapor. To this end it is recommended that all stations employ glass filters of the same composition and thickness. The meteorological observatory, Potsdam, is willing to procure and gage such filters. Special instructions on the nature and use of the filters will be prepared.

2. Since the investigations relative to a decision on a standard scale for pyrheliometric measurements are as yet uncompleted, it is recommended for the present to refer all measurements to the Smithsonian scale of 1913. Readings from instruments standardized in terms of the Angström scale can be reduced to the Smithsonian scale by the addition of 3.5 per cent.

It is recommended that the standard pyrheliometers to be used during the polar year be compared before and after the expedition at Upsala, Potsdam, or Washington.

In order to eliminate at a later date the falsifying influences of skylight in the measurements of direct solar radiation it is necessary to give, in addition to the type of instrument used, as exactly as possible the aperature conditions of the actinometer (length of tube, size of outer orifice, size of inner orifice, or size of the object-glass surface).

3. It is recommended that at favorably located polar stations, where there is available a sufficiently scientific personnel, there be carried out measurements of total

[1] To readers not familiar with recent literature on atmospheric turbidity, a brief statement of views held by different investigators may be helpful in interpreting the discussion at the conference.

Linke would include in atmospheric turbidity, T, all atmospheric depletion of solar radiation except that due to molecular scattering, which latter is easily computed from Rayleigh's equations. He represents atmospheric depletion by $e^{-a_1 T m}$.

Ångström represents atmospheric depletion by $e^{-(a_1+a_2)m}$, in which a_2 is the coefficient of scattering due to causes other than gas molecules, and including that which Fowle found associated with atmospheric water vapor. He expresses a_2 in the form $\frac{\beta}{\lambda^a}$ in which β is the atmospheric turbidity. The term does not include depletion through absorption by atmospheric gases, principally by water vapor. Under average conditions Ångström finds $a=1.3$, which, in contrast with λ^4 in the expression for molecular scattering, indicates that the diameters of the scattering particles are appreciably larger than the diameters of gas molecules.

insolation and of effective outward radiation. The instruments used are to be adjusted to standard apparatus. Suggestions for carrying out such measurements will be specially prepared.

4. Attention is called to the value of measurements of clearness of air, color of sky, anomalous refraction (measurements of the dip of the horizon), twilight, earthlight (Nachtschein), and zodiacal light. Details on the methods of these measurements have been drawn up by Professor Maurer (Zurich) and Dr. F. Schmid (Oberhelfenswil, Switzerland).

5. Special instructions on eye observations of the quantity and character of opalescent turbidity will be drawn up by Doctor Bergeron (Oslo).

6. As the value of the radiation constant there is recommended

$$\sigma = 8.26 \cdot 10^{-11} \cdot \text{cal/cm}^2 \cdot T^4$$
$$(5.76 \cdot 10^{-12} \cdot \text{watt/cm}^2 \cdot T^4).$$

In conclusion Herr Mörikofer reported his experiences in the gaging of cadmium cells and the advantages presented by taking into consideration relations of measurements with and without the employment of Minos glass (as a filter). Later, Herr Kühl presented curves from his new recording filtered potassium cell.

On Thursday, February 26, from 5:30 to 7 p. m. there was discussion of the methods of measurements with the cadmium cell; those taking part were Messrs. Büttner, Dubois, Feussner, Kühl, Mörikofer, and Süring.

(Signed) A. ÅNGSTRÖM.
R. SÜRING.
K. BÜTTNER.

FLYING WEATHER IN THE CORPUS CHRISTI AREA

By J. P. MCAULIFFE

[Weather Bureau Office, Corpus Christi, Tex.]

The "Corpus Christi area" as usually referred to by aviators in this section extends roughly from Beeville, 56 miles north, to Kingsville, 40 miles south, and George West, 70 miles west. In this small area there is considerable diversity of weather, usually effecting visibility and ceiling.

There are three elements most vitally effecting flying in this area, namely: Fog, wind velocity, and thunderstorms. These three handicaps to flying should be carefully studied by aviators in this area.

Records at the Corpus Christi Weather Bureau show that during the 44-year period, 1887–1930, inclusive, the average number of dense fogs has been as follows during the months indicated:

Month	Number of dense fogs	Month	Number of dense fogs
January	3	October	1
February	2	November	2
March	2	December	3
April	1		

During the other months of the year fog occurs so seldom that it is practically negligible.

A peculiar condition exists at Beeville. Fogs are much more frequent there, and within 5 to 10 miles each side, than they are at Corpus Christi. Many mornings when Corpus Christi and San Antonio report perfect visibility and ceiling, aviators run into dense fog at Beeville. Of course with weather reports from San Antonio and Corpus Christi at hand they fly high and soon come out into clear weather. Occasionally aviators have left Corpus Christi without first getting weather data, and in many of these cases they were forced to turn back when near Beeville, not attempting to fly farther, because they assumed that the fog continued northward.

The cause of these frequent fogs in the vicinity of Beeville seems to be due to the slope of the land eastward to the Gulf, the presence of San Antonio and Copano Bays that indent the coast line sharply in the latitude of Beeville, and probably also the Aransas River that flows past Beeville. These lowlands and water areas here cause air currents from the Gulf to flow westward, meeting the cold interior air, and causing fogs. In thickness and their local character these fogs resemble the mists and fogs of the eastern mountain regions. The frequency of these fogs leaves no doubt that a sharp temperature gradient exists in that locality, especially in the winter months. These fogs are not confined to any particular type of weather, but occur with high pressure, as well as when the barometer is low. They dissipate usually about 10 a. m., but occasionally persist until noon or the midafternoon. The average thickness of these fogs is 1,000 feet.

The second great handicap to safe flying is the wind velocity on this coast.

The writer's attention was first directed to the erratic wind velocities in this section by a letter from one of the officials of the T. A. T. Corporation. In his letter the official mentioned the fact that reports from San Antonio were frequently misleading, because the weather was subject to such erratic changes near Kingsville. He mentioned strong head winds as one of the annoying elements. This would be, of course, a strong southeast or south wind for the planes that were coming from San Antonio. The prevalence of these winds caused a readjustment of schedules by the T. A. T. It was noticed that the planes would enter these windy regions suddenly from a region that had given only moderate southerly breezes, and this windy condition almost invariably occurred within 10 miles of Kingsville. (The planes usually traveled on a course from San Antonio to Brownsville about 50 to 75 miles inland.) This strong wind that the planes encountered at this locality is the celebrated Corpus Christi sea breeze (1) that is always present when some atmospheric disturbance does not interfere with it. It extends for only a short distance inland, and for this reason is encountered only when near the Gulf waters. Kingsville is very close to Baffins Bay, a long narrow bay that extends westward from the Gulf for 30 or 40 miles. The sea breeze on this coast extends to a height exceeding 1,000 feet, and probably as high as as 2,000 feet, as observed by ceiling balloons and the movement of cumulus clouds. The sea breeze in the vicinity of Kingsville has about the same strength as at Corpus Christi and averages 16 to 25 miles per hour. Sometimes it reaches 30 miles per hour.

This annoyance can be avoided, somewhat, by aviators either going far inland and avoiding Kingsville, or swinging Gulfward north of Corpus Christi. The wind velocities are not so great on the Gulf beaches as they are on the shores of the bays. The sea breeze also causes another peculiar atmospheric irregularity, thunderstorms that are difficult to forecast.

From direct observation at Corpus Christi it has been found that thunderstorms occur two or three times more frequently at Robstown, 14 miles westward, than they

do at Corpus Christi. These storms can be seen forming during summer afternoons and sometimes the thunder can be plainly heard at Corpus Christi, while the sky is clear from the Gulf horizon to within 5 or 6 miles of Robstown. It is reported that this same condition occurs at Kingsville. The reason is, of course, convection. The swiftly moving sea breeze prevents the formation of these thunderstorms (2) near the bays, but just as soom as this breeze ceases convectional thunderstorms occur, just as they do in any interior section. Occasionally these storms cause hail, and generally dangerous squalls, so aviators are careful in this area to avoid them. They can easily be avoided by airplanes flying as close to the Gulf as possible, and this is generally the course advised during summer by all planes flying in this area. Sometimes the planes coming from San Antonio or Brownsville are caught unawares, and have to encounter these storms, but with available reports of storms prevailing in the interior, with clear sky near the coast, it is easy for pilots to steer a course that will avoid these dangerous phenomena. The severity of the coastal storms has been discounted by some writers who have witnessed thunderstorms in the Mississippi Valley or other interior regions. However, it should be remembered that while these thunderstorms are rather quiet, with the thunder generally high, they are very dangerous to airplanes, because they have very strong upward currents, erratic squall conditions, and often hail. As an illustration of the dangerous type of these coast storms, two incidents are cited here:

On the occasion of an aerocade in 1929 the Weather Bureau at Corpus Christi and Brownsville furnished information at intervals of two hours during the progress of the flight from Houston to Brownsville. At 1 p. m. the planes left Corpus Christi for Brownsville, with clear weather at Corpus Christi, and overcast at Brownsville. There had been a few thunderstoms during the morning. Near Kingsville the planes encountered rain; farther south thunderstorms were seen. All but 2 of the 24 planes turned back and returned to Corpus Christi. One of the planes that continued reached Brownsville safely, the other one was blown off its course, and landed in a desolate spot in Mexico 100 miles south of Brownsville.

The other case of note was a 4-passenger plan returning to Kansas City from Aransas Pass, 24 miles east of Corpus Christi. The weather forecast issued that morning from the Corpus Christi office was for local thundershowers. The pilot received this forecast by telephone from the local office, but nevertheless took off for his homeward flight. Within 10 minutes after the start he encountered a thunderstorm, attempted to fly through it, and crashed, killing all the occupants of the plane. This thunderstorm was one without much thunder, but from evidence obtained after the crash the plane was carried upward several thousand feet and dropped on the other side.

CONCLUSIONS

From the above stated facts it is seen that flying weather in the Corpus Christi area is practically uninterrupted during the five months, May to September, inclusive, in so far as the greatest hazard to flying is concerned—fog. During the other months of the year the elements to be watched are the strong and erratic winds on this coast, and thunderstorms.

Wet "northers" are also a great handicap to planes traveling northward. When they prevail the ceiling is low, sometimes below 700 feet and occasionally 500 feet. Careful pilots in this area generally ground their planes when one of these annoying "northers" is expected. On the average about three to five such disturbances will occur in each month, November to March, inclusive.

(1) Heckathorn, Charles E. MONTHLY WEATHER REVIEW, June, 1919, pp. 413–415 Land and Sea Breezes in the Vicinity of Corpus Christi.

(2) Tannehill, Ivan H. MONTHLY WEATHER REVIEW, Sept., 1921, pp. 498–499, Wind Velocity and Rain Frequency on the South Texas Coast.

PILOT-BALLOON OBSERVATIONS AT HAVRE, MONT.

By FRANK A. MATH

[Weather Bureau Office, Havre, Mont.]

Although numerous compilations of balloon and kite data have been published in the MONTHLY WEATHER REVIEW, it was thought that some of the more or less interesting results obtained with pilot balloons at Havre, Mont., during a period of three years and five months would add another chapter for study.

Whenever permissible, two balloon ascensions are made daily. The hours of observation were 6 a. m. and 2 p. m. from the beginning, August 6, 1927, to March 31, 1930, after which the hours were changed to 4.30 a. m. and 4.30 p. m. to work simultaneously with other stations. While a total of 2,487 observations were possible, at two a day, during the period from August 6, 1927, to December 31, 1930, there were 2,392, or 96 per cent, actually made. The visibility recorded with each according to the scale, 0 to 9, as given on page 29, Instructions for Making Pilot Balloon Observations, was as follows:

Observations	Visibility	Percentage
1,149	9	48
658	8	27
337	7	14
119	6	5
61	5	3
57	4	2
11	3	1

This indicates a high per cent of the number of possible ascensions and, as a rule, good visibility, over the plains of central Montana. A further indication of good flying weather is the small number, 95 "no ascensions" in three years and five months, or less than 4 per cent of total possible. Snow was the cause of preventing 48 of these "no ascensions"; rain, 26; low clouds, 10; fog, 8; high wind, 2; smoke, 1. In this connection it may be said that occasionally during low temperature in winter, a light dry snow falls with visibility 5 or 6. At such times balloons can be observed to altitude 1,000 to 2,000 meters.

There were 773 balloons reached an altitude of 4,000 meters or higher, 42 reached 10 kilometers (6.2 miles) or higher; and 13 reached 11 kilometers. The longest time that any one balloon was observed was one hour and 25 minutes, reaching an altitude of 15,390 meters (9.4 miles) on March 15, 1929, the highest of record for this station. The highest velocity computed from any balloon observation was 45.3 meters per second (101 miles per hour) on December 24, 1929. One of the balloons was observed to a distance of 44,600 meters (27.7 miles) away from Havre. That was the farthest of record by observation.

The bottoms of the paper lanterns attached to the balloons during darkness are stamped with the name of

the station and date. Six of the lanterns were picked up by farmers in remote places and mailed back to this office. The one returned from the most distant point was found on a farm near Ray, N. Dak., 32 miles northeast of Williston, or about 300 miles east of Havre. Others returned were found as follows: 15 miles southeast of Malta, Mont., about 100 miles east-southeast of Havre; one on King Island, Missouri River, about 82 miles southeast; one crossed the International boundary about 4 miles into Saskatchewan, 65 miles east-northeast of Havre.

FREE-AIR WINDS

A table showing surface-wind frequency and frequency resultants was compiled from data taken from page 13, Form 1001, recorded by register for each hour of the day. The registration was made by anemometer and wind vane 44 feet above the ground. The 4-year period, 1927–1930, was used in this table in order that it may be used in comparison with those of higher altitudes which follow. In this Table No. 1, surface winds favor a westerly movement with southwest prevailing, except that during the late spring month of May and the summer months of July and August the prevailing surface winds are east. June has a close race slightly in favor of southwest. The velocities, as a rule, are light to moderate, average about 6 miles per hour. The highest velocities are from a westerly direction. They occur mostly in winter, although the highest surface wind of record occurred during a summer squall in June.

Another table of surface wind direction frequency for Havre was prepared by E. R. Miller from data for the 13-year period, 1891–1902, MONTHLY WEATHER REVIEW, July, 1927, page 310. The two tables are much in agreement for all directions except northeast and east, which appear to be in reverse order. This is probably due to the difference in location of wind vane. During the 13-year period two different locations are involved and both are different from the location of the vane used in the later tabulation. The resultants of the later table, computed by the same formula, show a greater south component than the previous compilation.

Three other tables were prepared showing the percentage of times winds were observed from eight principal points of the compass and the velocities of the winds from the respective directions as computed from pilot balloon ascensions observed by the 1-theodolite method subject to any errors by this method as explained by Reihle, page 628, MONTHLY WEATHER REVIEW November, 1920. The data were compiled for altitudes, 801 meters, 1,530 meters, and 3,060 meters above the surface during the three years and five months ended December 31, 1930. The surface of Havre is 762 meters above sea level; the longitude, 109° 40′ west; the latitude, 48° 34′ north.

At the 801-meter level (2,628 feet), Table No. 2, the westerly winds are more decided than at the surface. The prevailing east direction of certain summer months has fallen to a smaller percentage being overcome by westerly winds. However, the velocities of all directions show a considerable increase, about double the surface easterly winds and about four times the westerly. Reihle, on page 629, MONTHLY WEATHER REVIEW. November, 1920, states, "A rapid increase in velocity from the ground to approximately 500 meters occurs at all seasons; above this there is little or no increase to 1,500 meters and there may be a decrease." This is true also for Havre, see Table No. 5.

The data in Table No. 3 at 1,530 meters, (5,020 feet) show the prevailing westerlies gaining more in per cent of times especially in the winter months. The percentage of easterly winds at this level in the winter season, November-March, is small, although during the summer, April-September, the easterly winds maintain a good percentage. Gregg has pointed out, page 234, MONTHLY WEATHER REVIEW, May, 1922, "The more striking features are: (1) The greater percentage of easterly winds at all levels in summer than in winter * * *." The average velocity of all directions remains close to, or slightly less than, at 801 meters.

Table No. 4, data at 3,060 meters (10,039 feet), shows a still greater increase in the percentage of times of the prevailing westerlies and a corresponding decrease in the easterly directions. From November 1, to about May 1, the percentage of easterly winds is very small, practically no east or southeast during January to April inclusive, although during May and June and September and October, a small percentage of easterly winds at this elevation is recorded. The velocities show an increase in most cases above the other levels. The highest velocities are westerly; the average from southwest through west and north being 11.4 meters per second, while from northeast through east and south is 4.8 miles per second.

The mean-frequency resultants of free-air winds at Havre for the whole period of balloon records are:

Surface	S 75° W
801 meters	N 85° W
1,530 meters	N 84° W
3,060 meters	N 81° W

Table No. 5 is a summary of the above data arranged to show the variation of the velocity and frequency percentages of the eight wind directions for the four seasons of the year from the surface up to 3,060 meters. The results shown by these tabulations, as a whole, agree to a great extent with those outlined by Gregg, MONTHLY WEATHER REVIEW, May, 1922, and by Reihle, MONTHLY WEATHER REVIEW, November, 1920.

TABLE 1.—*Surface wind frequency, and frequency resultants, Havre, Mont., for the four years, 1927–1930*

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultants
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	°
January	3	8	17	1	1	35	18	16	1	S. 79 W.
February	5	8	17	0	1	37	16	15	1	S. 78 W.
March	6	8	21	2	2	31	14	15	1	S. 80 W.
April	6	9	22	4	4	27	14	13	1	S. 69 W.
May	6	12	25	5	5	21	12	13	1	N. 34 W.
June	4	8	22	5	6	25	16	13	1	S. 61 W.
July	5	12	24	6	6	16	16	14	1	N. 18 W.
August	5	12	24	4	5	22	15	11	2	S. 64 W.
September	4	11	20	3	3	25	18	13	3	S. 88 W.
October	5	8	20	1	3	29	18	15	1	S. 84 W.
November	3	9	20	1	1	34	17	14	1	S. 73 W.
December	3	9	20	1	1	34	17	14	1	S. 73 W.

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE CONVERTED FROM MILES PER HOUR

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	2.1	1.9	2.0	0.8	0.9	5.2	2.5	2.3
February	2.5	1.7	2.2	0.0	1.3	5.2	2.5	2.8
March	2.8	2.0	2.2	1.9	1.4	4.8	3.0	3.4
April	4.6	2.7	3.2	2.1	1.7	4.5	3.3	3.4
May	3.1	2.4	3.1	2.3	1.8	3.8	3.2	3.4
June	2.5	1.8	2.3	1.9	1.7	3.9	3.3	3.6
July	2.4	1.8	2.2	2.0	1.6	2.9	2.3	2.9
August	2.4	1.8	2.1	1.4	1.3	2.8	2.0	2.5
September	2.4	1.8	2.0	1.3	1.8	3.4	2.5	3.2
October	2.8	1.8	2.1	1.2	1.3	4.4	2.9	2.9
November	1.7	1.9	2.4	2.0	1.1	5.3	2.4	2.9
December	2.0	1.7	2.3	0.7	1.1	5.7	2.7	2.6

TABLE 2.—*Percentage of time wind was observed from the following directions at 801 meters above the surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
January	165	5	3	1	1	3	10	38	39	0
February	150	7	1	1	1	1	22	31	36	0
March	166	8	5	4	2	4	18	35	24	0
April	164	10	4	6	9	4	19	34	14	0
May	174	7	8	9	13	9	17	24	13	0
June	163	4	7	9	14	4	15	28	19	0
July	178	10	7	9	8	9	17	24	16	0
August	226	5	5	10	11	9	17	24	19	0
September	220	9	4	7	7	7	14	29	23	0
October	226	7	2	2	10	4	21	37	17	0
November	209	4	2	2	5	4	14	39	30	0
December	215	2	1	1	2	4	14	46	30	0

AVERAGE VELOCITIES, MILES PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	7.9	3.3	1.9	1.8	5.4	5.9	13.8	12.3
February	8.6	4.2	2.7	3.5	4.7	12.2	13.7	11.2
Mrach	7.0	3.0	4.2	10.0	4.7	11.1	12.7	9.8
April	5.7	4.0	7.3	10.9	5.3	7.4	11.1	7.3
May	6.0	5.1	8.5	9.8	5.9	7.0	10.2	7.1
June	5.4	3.9	8.6	4.6	4.9	5.5	10.5	10.0
July	4.7	5.8	7.0	5.9	4.0	5.7	7.4	7.5
August	4.9	3.1	5.9	5.9	5.5	5.9	7.9	6.4
September	6.1	4.7	3.4	4.5	5.0	6.6	9.0	8.3
October	5.0	6.7	5.0	4.5	8.1	9.4	12.5	10.1
November	9.4	6.0	5.9	4.4	4.4	11.7	13.5	10.9
December	11.0	3.6	6.5	4.9	5.1	10.1	15.4	10.7

TABLE 3.—*Percentage of time wind was observed from the following directions at 1,530 meters above surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
January	133	5	1	0	2	1	10	33	48	0
February	125	6	0	0	0	1	11	37	45	0
March	140	9	1	2	0	1	14	44	29	0
April	144	3	2	3	6	6	15	42	23	0
May	160	9	8	3	6	9	19	35	11	0
June	153	6	2	7	6	10	16	35	18	0
July	169	5	5	5	5	10	24	31	15	0
August	216	5	2	2	10	10	21	30	20	0
September	196	8	2	2	5	11	18	30	24	0
October	201	5	4	3	3	4	12	48	21	0
November	174	5	0	1	1	5	9	45	34	0
December	175	3	1	1	1	4	7	39	44	0

TABLE 3.—*Percentage of time wind was observed from the following directions at 1,530 meters above surface; period August 6, 1927–December 31, 1930*—Continued

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	9.0	2.3	0	3.8	3.0	7.1	13.9	13.0
February	8.9	0	0	0	8.2	11.1	13.5	12.2
March	6.4	7.2	6.9	0	7.4	9.9	13.2	10.8
April	8.1	4.2	5.1	9.7	5.0	8.0	10.0	13.0
May	6.7	4.1	5.6	5.3	6.8	5.5	9.8	6.9
June	4.3	3.0	6.9	4.9	5.5	6.4	10.1	9.9
July	5.6	4.7	2.9	5.6	3.6	5.8	8.5	6.2
August	3.4	6.4	2.2	4.8	5.0	6.0	7.4	7.0
September	6.8	3.8	4.7	4.8	5.6	6.7	9.6	9.9
October	5.8	3.5	3.2	4.5	3.1	8.6	11.5	11.8
November	8.6	0	10.1	3.8	5.9	9.4	13.2	13.5
December	9.2	3.2	2.3	3.4	6.4	11.1	13.6	12.7

TABLE 4.—*Percentage of time wind was observed from the following directions at 3,060 meters above surface; period August 6, 1927–December 31, 1930*

	Number of observations	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm
		P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
January	56	6	2	0	0	0	2	34	56	0
February	58	12	2	0	0	2	9	36	39	0
March	73	15	1	0	0	0	4	52	28	0
April	84	4	2	0	0	2	19	49	24	0
May	121	9	3	3	3	5	19	41	17	0
June	109	5	3	2	2	6	18	38	26	0
July	146	3	0	1	0	1	27	51	17	0
August	170	2	1	1	2	5	22	47	20	0
September	119	4	3	3	1	6	15	35	33	0
October	120	2	3	2	2	3	12	48	28	0
November	89	6	1	0	4	1	7	39	42	0
December	69	12	0	1	3	3	7	35	39	0

AVERAGE VELOCITIES, METERS PER SECOND, OF THE RESPECTIVE DIRECTIONS ABOVE

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
January	13.8	8.4	0	0	0	3.2	13.1	16.2
February	15.1	16.2	0	0	8.7	10.0	14.6	13.1
March	10.5	7.3	0	0	0	11.4	14.4	13.9
April	9.1	13.0	0	0	4.7	9.2	12.3	12.5
May	5.3	5.7	3.4	5.6	10.4	10.5	10.3	11.3
June	6.5	2.4	5.4	7.1	9.9	9.3	12.3	10.7
July	7.1	0	5.0	0	6.9	13.0	11.9	7.9
August	7.7	1.1	7.7	7.2	6.6	10.8	11.5	9.2
September	8.9	3.9	6.5	6.2	7.8	12.7	11.3	13.1
October	7.6	8.9	6.5	5.9	13.4	11.4	13.3	14.2
November	14.6	3.2	0	1.2	4.9	12.4	13.7	15.5
December	13.3	0	3.2	5.3	9.2	8.7	13.1	16.0

TABLE 5.—*Seasonal winds at different altitudes*

SUMMER

Altitude	North		Northeast		East		Southeast		South		Southwest		West		Northwest		Calm
	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Velocity (m. p. s.)	Per cent	Per cent
Surface	2.4	5	1.8	11	2.2	23	1.8	5	1.5	6	3.2	21	2.5	16	3.0	13	1
801 meters	5.0	6	4.3	6	7.2	9	5.5	11	4.8	7	5.7	16	8.6	25	8.0	18	0
1,530 meters	4.4	5	4.7	3	4.0	15	5.1	7	4.7	10	6.1	20	8.7	32	7.7	18	0
3,060 meters	7.1	3	1.2	1	6.0	1	4.8	1	7.8	4	11.0	22	11.9	45	9.3	21	0
AUTUMN																	
Surface	2.3	4	1.8	9	2.2	20	1.5	2	1.4	2	4.4	29	2.6	18	3.0	14	2
801 meters	6.8	7	5.8	3	4.8	4	4.5	7	5.8	5	9.2	16	11.7	35	9.8	23	0
1,530 meters	7.1	6	2.4	2	6.0	2	4.4	3	4.9	7	8.2	13	11.4	41	11.7	26	0
3,060 meters	10.4	4	5.3	2	4.3	2	4.4	2	8.7	3	12.2	11	12.8	41	14.3	34	0
WINTER																	
Surface	2.2	4	1.8	8	2.2	17	0.5	1	1.1	1	5.4	37	2.6	17	2.6	15	1
801 meters	9.2	5	3.7	2	3.7	1	3.4	1	5.1	3	9.4	15	14.3	38	11.4	35	0
1,530 meters	9.0	5	1.8	1	0.8	1	2.4	1	5.9	2	9.8	9	13.7	36	12.6	46	0
3,060 meters	14.1	10	8.2	1	0.0	0	1.8	1	6.0	2	7.3	6	13.6	35	15.1	45	0
SPRING																	
Surface	3.5	6	2.4	10	2.8	23	2.1	4	1.6	4	4.4	26	3.2	13	3.4	14	1
801 meters	6.2	8	4.0	6	6.7	6	10.2	8	5.3	6	8.5	18	11.3	31	8.1	17	0
1,530 meters	7.1	7	5.2	4	5.9	3	5.0	4	6.4	5	7.8	16	11.0	40	10.2	21	0
3,060 meters	8.3	9	8.7	2	1.1	1	1.9	1	5.0	2	10.4	14	12.3	47	12.6	23	0

EVAPORATION IN THE EASTERN CARIBBEAN

By C. L. RAY

[Weather Bureau Office, San Juan, P. R., February 10, 1931]

Dependable mean values of evaporation may be had, as a rule, from a comparatively short period of observations, namely 10 years, more or less. The reasons are obvious: The primary influences affecting evaporation are temperature, vapor pressure, and wind velocity under 20 miles per hour, meteorological factors with a greater tendency to repeat themselves by months or seasons than is true of rainfall. This is true in greater degree in the latitude of the eastern Caribbean than elsewhere, due to the steadiness of the easterly "trades" throughout the year and the uniformity of the temperature. The stations considered in the present paper are San Juan, P. R., lat. 18° 29′ N., period of record, 1917–1930; St. Croix, Virgin Islands, lat. 17° 46′ N., 1920–1930; and Kingston, Jamaica, lat. 18° 1′ N., 1924–1930.

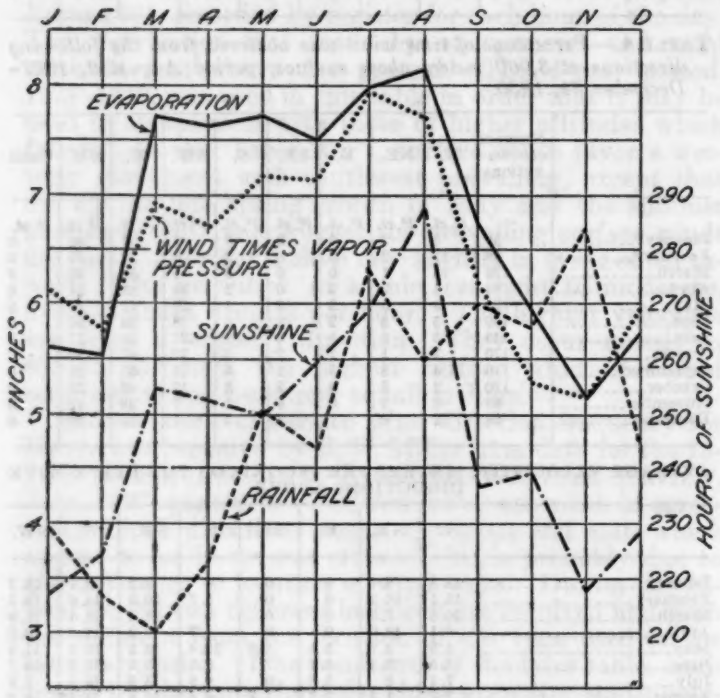

FIGURE 1.—San Juan, P. R. Evaporation (1917–1928) and related factors

At San Juan, 48 feet above mean sea level, the equipment consists of the standard evaporation pan, still well, and gage, of type similar to that in use in the continental United States since 1916. Daily observations at 8 a. m., E. S. T., include the 24-hour evaporation, rainfall, dry and wet bulb temperatures, hours of sunshine, and wind movement. The anemometer is placed at the surface of the water. Records of the average evaporation together with related data appear in Table 1, covering the three stations mentioned. In Figs. 1 and 2, graphs of the San Juan and St. Croix record are based upon Table 1, except for the omission of the years 1929–30 from the San Juan averages to allow for a comparable time period of wind mileage.

Referring to the monthly and annual values (not included in the published text), the maximum annual evaporation occurred in 1917, amounting to 88.988 inches, the secondary maximum in 1918, 87.724 inches. Wind mileage in 1917 and 1918 was between 47,000 and 49,000 miles, in 1917 being the second highest mileage on record and in 1918 the third greatest. The extreme maximum mileage occurred in 1922, exceeding 51,000 miles, during which year evaporation amounted to 82.133 inches. The year of least evaporation was 1930 (71 inches) for which period exact wind movement at the ground level is not available. The second and third lowest evaporation years were 1925 and 1927 during which occurred the extreme minimum and third lowest mileage. The effect of the wind factor is thus well defined in most instances. The maximum monthly evaporation occurred in July, 1917, amounting to 10.089 inches, the maximum wind mileage also occurring in the same month (6,323 miles); the least evaporation occurred in November, 1918, 3.999 inches, comparing with the low wind movement of 1,895 miles.

In the graph, Fig. 1, supplementing the evaporation and rainfall is shown the trace of monthly wind movement times the vapor pressure deficit, using the dry bulb and dew point vapor pressures in obtaining the latter value. A trace of the monthly variation in hours of sunshine is likewise charted. Both rather closely parallel the line of evaporation through the year. In the equation of Fitzgerald (MONTHLY WEATHER REVIEW, 1904, Evaporation Observations in the United States, by H. H. Kimball) $E=0.3984\ (e_s-e_d)\ (1+.0208W)$ where e_s-e_d equals the vapor pressure deficit and W the wind mileage at the surface of the water, respectively, we obtain an evaporation some 25 per cent in excess of the measured readings at San Juan. The monthly values for this equation are included at the foot of Table 1. The rainfall totals at

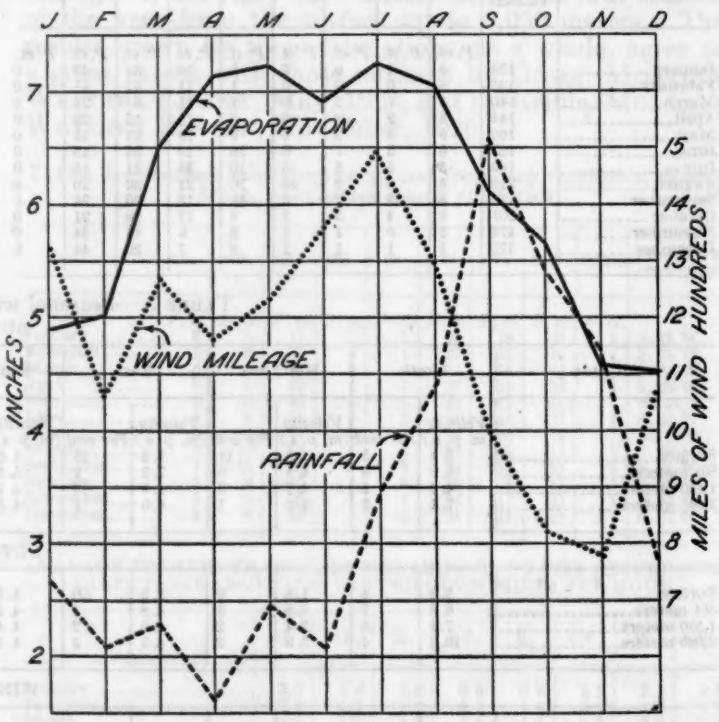

FIGURE 2.—St. Croix, Virgin Islands. Evaporation (1920–1930) and related factors

the station exceed evaporation in November, practically balance it in October, and are markedly below it through the other months. The greatest difference occurs in March with 4.6 inches excess of evaporation over rainfall.

The Christiansted, St. Croix, Virgin Islands, station is maintained by the Weather Bureau as a cooperative station. It is not equipped with a sunshine recorder,

nor are readings made of the wet-bulb temperature, vapor pressure, or humidity, but otherwise it is of the standard evaporation type, readings being made daily, including dry temperature, and wind mileage at the water level. Referring to Table 1 it will be noted that extreme monthly and annual values agree in general with the extremes at San Juan. Uniformly lower evaporation amounts, compared with San Juan, are accounted for largely, it would appear, by the lower wind movement. The elevation of the station is 25 feet above mean sea level, the lower wind velocities evidently due to local peculiarities of topography and exposure. The maximum evaporation at the station is registered as a rule in July, the minimum in November and December. The extreme maximum wind mileage occurs in July, the extreme minimum in November. Rainfall exceeds evaporation in September and November, approximately equals it in October, while falling well below in the remainder of the year. Fig. 2 shows the graphical picture of St. Croix evaporation over the 11-year period.

At Kingston, Jamaica, the data consist of monthly and annual measurements of evaporation over a period of seven years (1924 to 1930), including mean temperature and rainfall. The mean annual rainfall is less than 25 inches. Kingston is 59 feet above mean sea level. Wind movement is comparatively lower than that obtaining at San Juan and probably more nearly comparable to conditions at St. Croix. The vapor pressure deficit as indicated from the records available for a single year, 1901, show higher values than occur at San Juan, as would be supposed, in harmony with higher temperatures and a generally drier climate. Comparing the monthly values of the vapor pressure deficit for the year 1901 with the average monthly figures of evaporation (seven years), we find, as would be expected, extreme maximum evaporation values occurring in April and May, in coincidence with markedly larger vapor pressure deficit in those months. In Fig. 3 comparative data for the seven years (1924–1930) are given for Kingston, St. Croix, San Juan, and Balboa Heights, Canal Zone. The influence of the dry winter period at Panama is shown in the high evaporation values during the months of January to March, inclusive.

The excessive evaporation in the eastern Caribbean area is of course quite largely the result of the steady trade winds throughout practically all the year and the long daily periods of sunshine and high temperatures. The loss of moisture from land areas would be a serious problem for agriculture but for the frequent rains that occur in much of this section. In Porto Rico droughts are not generally of severity except on the south side of the island. The mountainous interior, extending from east to west, separates the area on a 70-30 basis, moisture-bearing winds leaving the great part of their precipitation on the 70 per cent northern side with consequent normally light rainfall south of the divide. The hurri-

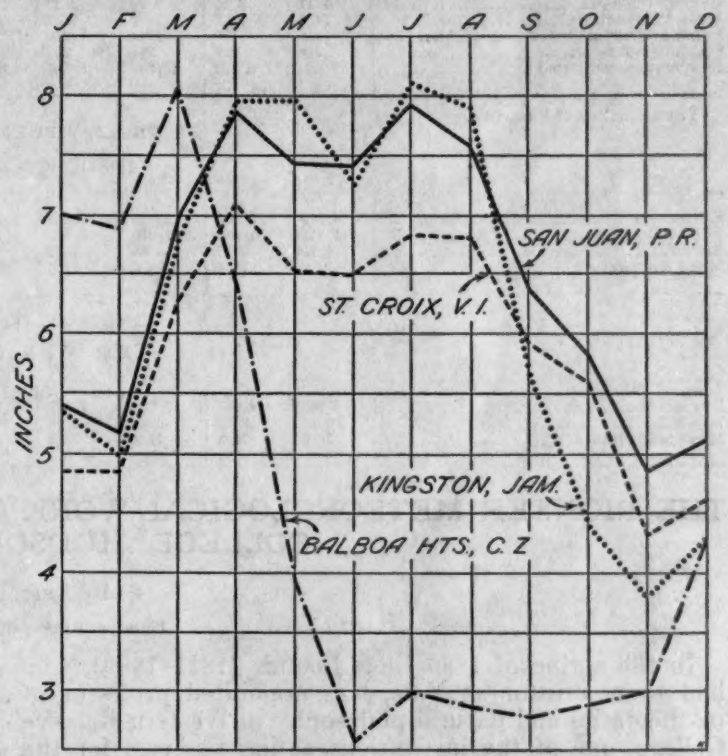

FIGURE 3.—Evaporation (1924–1930) San Juan, P. R., St. Croix, Virgin Islands, Kingston, Jamaica, and Balboa Heights, Canal Zone

cane season frequently proves a boon to the latter portion of the island if not actually extending its influence farther north. Thus, tropical storms, passing to the south of Porto Rico, often result in beneficial rains on the south side of the island without damaging winds affecting the area. Irrigation however is the main dependence through much of the south portion. Evaporation is probably considerably greater than in the northern part, due to the drier atmosphere, greater amount of effective sunshine and higher temperatures.

TABLE 1.—*Evaporation and related factors*

SAN JUAN, P. R. (1917–1930)

[Lat. 18° 29′ N., long. 66° 7′ W.]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Evaporation	5.558	5.533	7.615	7.848	7.743	7.427	8.143	8.053	6.615	5.870	5.081	5.462	80.948
Wind mileage	3,975	3,397	4,089	3,567	3,401	3,407	4,322	3,801	2,561	2,106	2,366	3,723	40,716
Rainfall (inches)	4.11	3.15	2.90	3.32	5.12	4.65	5.74	5.50	5.95	5.41	6.37	4.64	56.86
Mean temperature	74.5	74.5	75.0	76.2	78.6	79.3	79.6	80.2	80.2	79.6	78.0	75.9	77.6
Vapor pressure deficit	.158	.160	.211	.230	.248	.245	.237	.248	.237	.218	.198	.177	
Sunshine hours	218	224	254	252	249	259	269	288	237	239	218	228	
Evaporation computed [1]	7.025	6.322	10.049	9.591	10,097	9.611	11.361	11.036	7.806	6.500	6.256	7.399	103.053

[1] From equation of Fitzgerald.

ST. CROIX, VIRGIN ISLANDS (1920–1930)

[Lat. 17° 46′ N., long. 64° 45′ W.]

Evaporation	4.779	5.005	6.535	7.202	7.241	6.909	7.249	7.098	6.141	5.731	4.550	4.537	72.977
Wind mileage	1,312	1,046	1,270	1,172	1,230	1,364	1,499	1,302	1,009	820	792	1,082	13,898
Rainfall	2.70	2.10	2.31	1.62	2.40	2.00	3.34	4.35	6.59	5.50	4.72	2.83	40.46
Mean temperature	75.9	75.4	76.0	77.6	79.6	80.9	81.4	81.6	81.1	79.9	78.2	76.6	78.7

KINGSTON, JAMAICA (1924–1930)

[Lat. 18° 1′ N., long. 76° 48′ W.]

Evaporation	5.463	4.997	7.020	7.987	7.920	7.289	8.121	7.911	5.457	4.377	3.757	4.324	74.623
Rainfall	0.37	0.69	0.42	0.94	1.78	0.63	1.14	4.39	3.30	6.00	3.25	0.99	23.90
Mean temperature	76.6	76.3	77.4	78.4	80.3	81.4	81.8	81.7	81.1	80.1	79.0	77.2	78.7

THE PIONEER METEOROLOGICAL WORK OF ELIAS LOOMIS AT WESTERN RESERVE COLLEGE, HUDSON, OHIO, 1837–1844

By ERIC R. MILLER

[Weather Bureau Office, Madison, Wis.]

In the spring of 1836 Elias Loomis (1811–1889), who had been a tutor at Yale, was appointed professor of mathematics and natural philosophy in Western Reserve College, one of the institutions acting as hosts for the meeting of the American Meteorological Society at Cleveland in 1930. Western Reserve College had been founded in 1826 at Hudson, Ohio, about 20 miles southeast of Cleveland, as a sort of Yale in Ohio by the Connecticut people who had first settled the region.

Loomis's salary was to be $600 per annum, but there was an economic depression in progress then as now, so that so much of his salary as was not paid in kind remained in arrears, and when he left Hudson the college offered to deed him some of its unimproved lands (1). He was allowed to spend the first year of his professorship in Europe, where he attended the lectures of Arago, Biot, Dulong, Poisson, and Pouillet in Paris, and bought apparatus there and in London, but did not have money enough to go to Germany. In the autumn of 1837 he returned to Hudson to teach and investigate for the next seven years. The chief objects of his researches were terrestrial magnetism, auroras, and storms.

Intense interest in storms had been aroused by the publications of Redfield, Espy, Dove, Reid, and Piddington, of whom Redfield and Espy had become involved in a hot controversy over the air circulation in tropical cyclones (2). To put the rival theories to the test of experiment, Loomis set about collecting all available data "on the storm which was experienced throughout the United States about the 20th of December, 1836," as the title of his paper runs (3). This storm was selected because it occurred within a period recommended by Sir John Herschel for hourly meteorological observations. The extent to which Americans were then cooperating in international meteorology is indicated by all of the phenomena having been recorded hourly at eight stations—Baltimore, New York, Albany, Flushing, New Haven, Gardiner, Montreal, and Quebec. Loomis obtained barometer readings from 27 stations, and other information from stations distributed over most of the country east of the Rocky Mountains, as well as from Bermuda, the West Indies, and from a ship on the Pacific coast.

He mapped this storm at 6-hour intervals, studying the pressure, temperature, wind direction and velocity, and precipitation. The center passed north of all of the observers, but he made a remarkable study of the phenomena of the cold front, of which his paper contains an isochronal map showing how it swept across the country. To illustrate the lines on which he attacked his problem, the following is quoted from this paper:

> But how is it possible for two winds not far separated from each other to blow violently toward each other for hours and even days in succession? Let us make a simple numerical estimate. The wind blew from the northwest at least 40 miles per hour. This gives a progress due east of more than 28 miles per hour, and is fully equal to the average progress of the barometric minimum. The atmospheric wave, then, progressed with not far from this velocity with which the wind was observed to blow, but in order to allow an opportunity for this onward progress, the wind in advance of the wave must retire, and that with the same velocity with which the northwest wave approaches. * * * The conclusion is inevitable that the northwest wind displaces the southeast wind by flowing under it. * * * The southeast current found its escape by ascending from the surface of the earth. Having quit the surface, it might either flow on in its first direction over the northwest current, or it might be driven back over the southeast current, or both of these motions might exist simultaneously. When we come to consider the cause of the rain, we shall be able to judge of the probability of these several suppositions.

After discussing radiation, advection, mixing, and "air suddenly transported into elevated regions" he observes that "the fourth cause of precipitation must be allowed to be by far the most efficient of all."

> Snow and hail (ice pellets?) did fall at nearly all of the northern stations after the northwest wind set in, but the amount was small, much less than must necessarily result if the entire southerly

wind had flowed over the northerly and had its moisture precipitated by it. Still, it seems probable that a part of the southerly wind did continue on its course and produce the snow which was observed to fall. I infer that the current was mainly turned back upon itself so that the moisture as fast as precipitated fell through the lower current still blowing from the southeast. My idea may best be illustrated by a diagram (p. 159).

The diagram anticipates with remarkable exactness the form of a cold current underrunning still, warm air, found experimentally by W. Schmidt (4).

A tornado in northeastern Ohio in February, 1842, started Loomis studying two storms of that month. His paper on these storms (5) created a great sensation at the centennial meeting of the American Philosophical Society in May, 1843, both on account of the light that it shed on the theories of Redfield and Espy, and still more by reason of his invention of the synoptic weather map with isobars and isotherms. He had no means of reducing the barometer to sea level so that he was obliged to draw isobars of equal departure from normal. His paper is illustrated with 13 of these maps, 7 showing the progress of the parent storm of the tornado from February 2 to 5, 1842, the other 6 show the storm of February 15–17, 1842, both at 12-hour intervals. Brandes at Leipzig had constructed similar maps in 1820 and 1826, but did not publish them. Loomis was apparently unaware of the work of Brandes, and is in any case entitled to the credit of first publication.

In this paper again, Loomis is concerned with the thermodynamics of ascending and descending air, and quotes the observations and experiments of Poisson, Gay-Lussac, Forbes, Pouillet, Leslie, and especially the experiment of Clement and Desormes which is still repeated by sophomores in the college course in physics to-day. The following quotation (p. 174) shows one of Loomis's applications of the theory:

As the westerly wind pours over the (Allegheny) mountains and descends to the level of the sea it comes under greater pressure, and heat is developed which dissolves the vapor, producing clear sky. Thus clear sky succeeds a storm much sooner on the eastern than on the western side of the mountains.

This paper also contains two anticipations of the Bjerknes Polar Front theory (p. 178). "These oscillations are propagated by the laws of waves." On page 180 he charts the instantaneous directions of the winds in two cyclones and shows that these consist of two streams of air, of which the northwest current revolves in an inflowing spiral around and impinges against the side of the southeast current.

Loomis numbered among his students at Western Reserve College an energetic fellow, Halbert E. Paine, who rose to be major general of Volunteers in the Civil War, was elected to Congress while yet in camp, and afterward was appointed Commissioner of Patents. In the second of these capacities Paine put through Congress in the record time of seven days the act that started our present national weather service.

Loomis went to the University of New York in 1844, where he wrote many of the textbooks that made him famous and wealthy. He succeeded Joseph Henry at Princeton when the latter became the first secretary of the Smithsonian Institution, but Loomis was induced to return to New York the following year and remained

until 1860 when his alma mater, Yale, called him to the professorship that he held the remainder of his life. His Treatise on Meteorology was published in 1868. Beginning 1874 he presented a series of 23 contributions to meteorology to the National Academy of Sciences.

Loomis's prestige was used by Henry to support the extensive meteorological program of the Smithsonian Institution when it was organized in 1847, and by Paine again in 1870 when the meteorological work was initiated under the chief signal officer of the Army, which has developed into the present United States Weather Bureau.

Loomis passed away in 1889 at the age of 78. His fortune of $300,000 derived from his text-books, left to Yale University, was the largest bequest received up to that time by that institution.

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(4) Schmidt, W. Zur Mechanik der Boen, Met. Zeit, vol. 28, 1911, p. 355–362.

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GREAT DUST STORM IN WASHINGTON AND OREGON, APRIL 21–24, 1931 [1]

By DONALD C. CAMERON

[Weather Bureau Airport, Portland, Oreg.]

SYNOPSIS

A considerable part of Washington and Oregon experienced on April 21–24, 1931, an extraordinary dust storm borne on strong northeast winds that were common to both States, although of greater force in some parts than in others.

A week previous saw the end of a rather protracted wet spell in both States which was succeeded by clear skies very low relative humidity under which the top layers of the soil had dried out very thoroughly so that the strong northeast winds that occurred on the 21st whipped up great quantities of dust from the wheat country and the semiarid parts of the interior and carried westward and southward as a dust cloud of great magnitude that subsequently blew itself out over the Pacific Ocean. The strength of the wind was such as to overcome and blow down frail structures and even great trees. So high winds were quite exceptional for the time and place. Forest and brush fires broke out suddenly over much of the territory invaded by the dust storm; the very low relative humidity and poor visibility made fire suppression very difficult.

The winds subsided during the night of the 22d and 23d and during the daylight hours of the 23d but a smoke pall continued for several days in the territory affected.

The strong northeast winds were due to the presence of a large mass of cool dense air centered over the northern part of the Province of Alberta and especially to the relative position of this cool air mass with respect to one of higher temperature and less density than occupied the northern border States of Idaho, Montana, and the Great Basin. The isobaric chart, Figure 1 shows an isobar of 30.7 inches open to the northward, thus marking the

[1] Somewhat condensed from the original.—ED.

southward extension of the denser air and as shown by the wind arrows an air movement toward the less dense air mass over the Great Basin has already set in. Normally there is a flow of air from regions of great air density to regions of less density. Figure 2 shows the isobaric situation 12 hours later than Figure 1 and it also

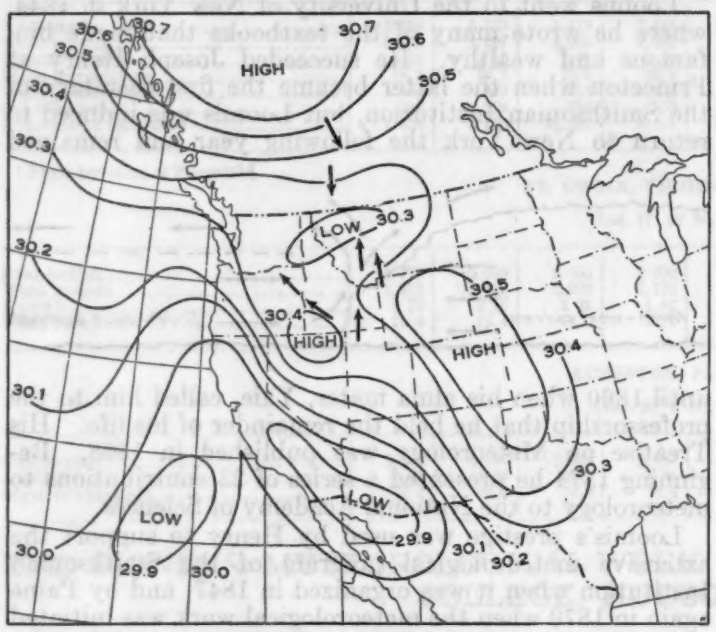


FIGURE 1.—Isobaric chart 5 a. m. 120th meridian time April 21, 1931

shows by the shaded area over Washington that the dust storm had already taken tangible form; the subsequent charts portray the regions of great dust intensity by solid shading.

The strength of the northeast winds during the 21st was augmented by a very pronounced fall in atmospheric

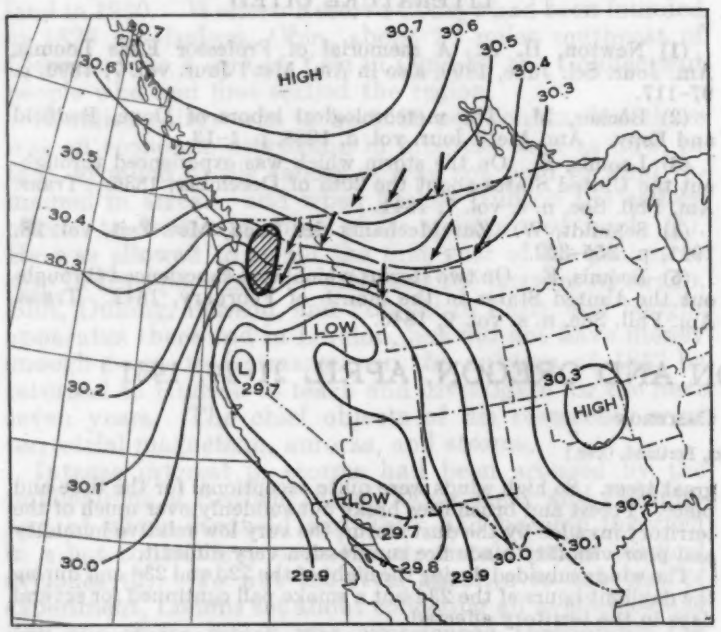


FIGURE 2.—Isobaric chart 5 p. m. 120th meridian time April 21, 1931. Shaded area shows position of duststorm and arrows wind direction

pressure over southwestern United States and up to Oregon and southern Idaho best shown by Figure 3 on which the difference in pressure between the cool, dense air in the northeast and the less dense over the Great Basin is 1.35 inches. This great difference in pressure supplied the energy of the northeast winds as manifested in the destruction of frail structures, the blowing down of great trees and uprooting of others as shown on the inset sheet. (Fig. 6.)

The next chart of the series, Figure 4, marks the end of the dust storm. The pressure level in the cool dense

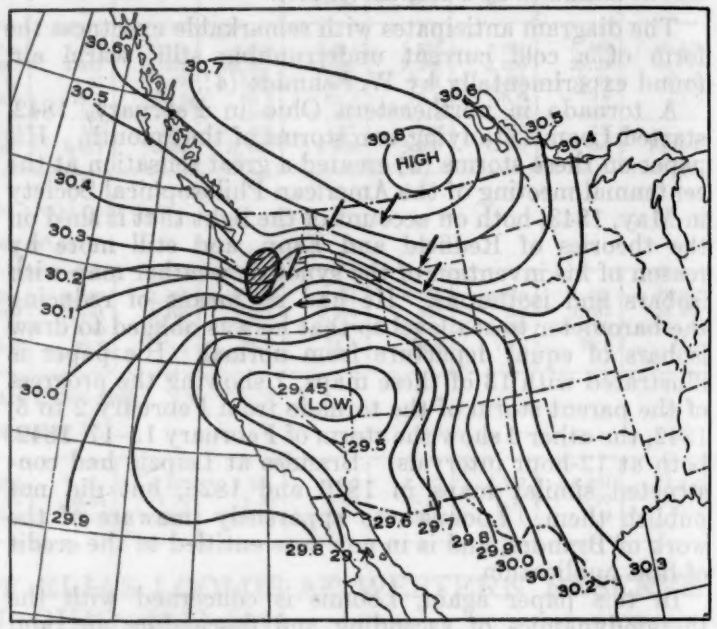


FIGURE 3.—Isobaric chart 5 a. m. 120th meridian time April 22, 1931. Wind direction by arrows and position of dust storm in solid shading

area has fallen four tenths of an inch and the pressure situation has drifted so far to the east and south as to no longer control the wind circulation in Washington and Oregon.

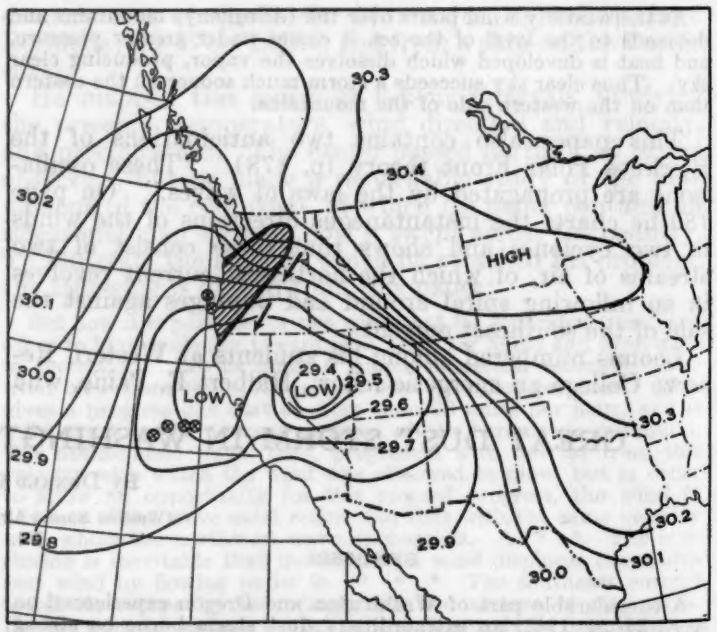


FIGURE 4.—Isobaric chart 5 a. m. 120th meridian time April 23, 1931. Crosses show approximate positions of vessels that observed dust storm; solid shading, position of dust storm; wind directions by arrows

The progress of the great dust front is graphically shown in Figure 5 based upon reports from airway and other stations.

The arrival overhead of the colder air at Pasco, Wash., was heralded by increasing cloudiness and light drizzling rain. At 2 p. m. Pasco's wind had become southeast, 15 m. p. h. but at Arlington in the northwestern part of the State the wind increased to *northeast strong* from *east*

(To face p. 197)

FIGURE 6.—Wind destruction: Upper shows abandoned orchard trees uprooted by the northeast gales; lower, a mountain home and outbuilding crushed by heavy timber (near base of Mount Hood)

UNIV. OF HAWAII

light and "sand storm" was reported.[2] At Umatilla on the Columbia River about 200 miles southeast of Arlington dust clouds were observed to the westward. Grand Dallas near to Dalles and close to the eastern entrance to the Columbia River Gorge reported dust clouds visible to the east. During this period (p. m. of 21st) the barometer was rising at Spokane, Pasco, and Walla Walla, clearly indicating the approach overhead of colder air; at the same time, however, an unusual fall in the barometer was taking place at Burns, Oreg., and Boise, Idaho (0.20 inch in 3 hours), thus tending to greatly increase the strength of the northeast winds.

The advancing northeast wind was a deep one, as evidenced by the pilot-balloon run at Spokane, Wash., at 3 p. m. when northeast gales were observed to the top of the run at about 5,000 feet; the great height was also evidenced by the experience of a Varney mail plane which left Pasco about 1 p. m. of the 22d climbed to the level of 14,500 feet in an effort to surmount the dust cloud. The pilot lost sight of the ground below and when he recovered his bearings the waters of the Pacific came into view near Seaside, Oreg., about 60 miles west of Portland. The strength of the tail wind had been underestimated by the pilot and his plane passed its destination.

The free-air winds above Paso, 3 p. m. of the 22d, were as follows:

At 700 feet 40 m. p. h.
At 1,400 feet 77 m. p. h.
At 2,000 feet 78 m. p. h.
At 2,600 feet 71 m. p. h.

Space does not permit the recital of the items of interest that were reported during the passage of the dust cloud from Tacoma on the north to Mount Shasta on the South. The continuation of the storm over the Pacific is described in the following.

THE DUST STORM CONTINUES OVER THE PACIFIC [3]

Five vessels navigating the Pacific near the west coast of the United States encountered the dust storm hereinbefore described on April 22, 23, and 24. The vessels have been listed and the remarks in reference to the storm are given in tabulated form following.

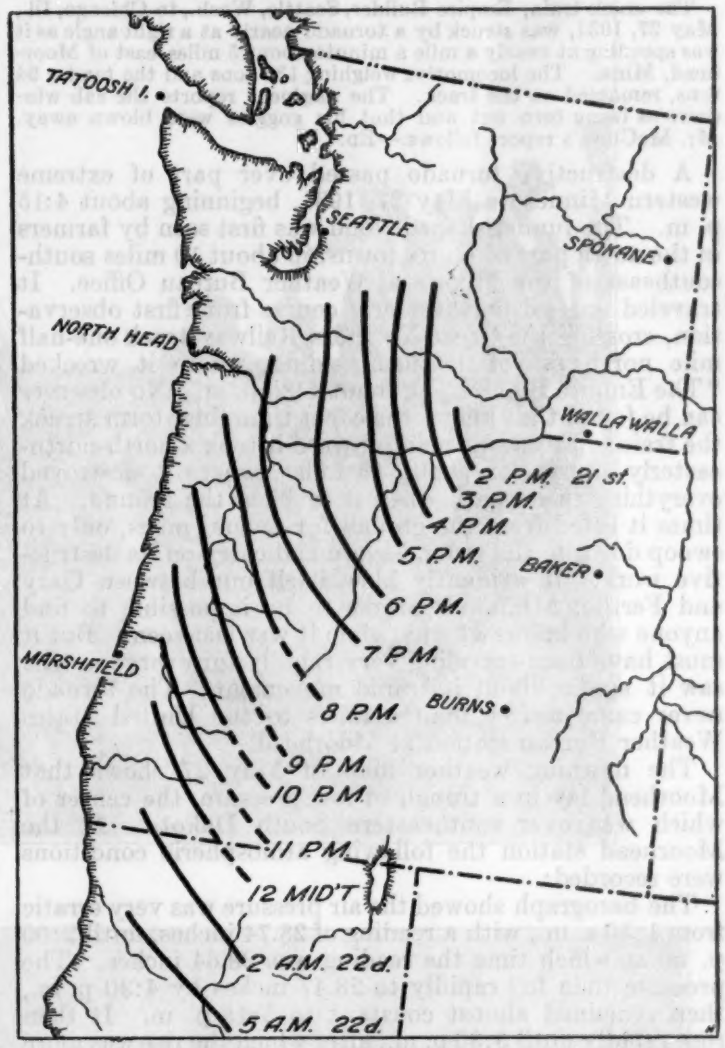


FIGURE 5.—Dust-storm fronts, hourly, as it passed over Washington, Oregon, and California

Vessels encountering dust storm in east Pacific

Name	Latitude	Longitude	Date and time	Wind direction and force	Remarks
	° ′	° ′			
Albertolite	44 06 N	125 00 W	22d	NE. 6	Visibility so low it necessitated navigating as in fog. At this time the atmosphere was filled with fine particles of dust or sand and there was a distinct odor of smoke.
Emma Alexander	43 31 N	124 46 W	22d	NE. 6	Ship ran into a heavy dust storm—dust covering entire ship and shutting off visibility to the extent that it was necessary to sound the whistle.
Mericos H. Whittier	36 45 N	125 47 W	22d	NW. 6	When first encountered it was considered a low fog bank; visibility was restricted to about 3 miles and the sky was perfectly clear. But when daylight arrived it was noticed that the ship had a coating of fine brown-colored dust all over. During the 23d the dust bank remained at practically the same consistency throughout the day having an altitude of about 30° but from 5 p. m. it was noticed to be getting thicker and visibility decreased to about 1¼ miles. During the early morning of the 24th the wind backed to SSW. 2 the dust gradually thinning until at 8 a. m. the atmosphere was quite clear except for the haze caused by falling rain. The ship's position at this time was lat. 34° 30′ N., long. 131° 45′ W.
Somme	36 34 N	127 30 W	23d	W. 2	Found heavy coat of fine brown dust that looked like volcanic ash.
Maui	36 20 N	127 19 W	23d	NNW. 3	Apr. 23 at 5 a. m. lat. 36° 20′ N.; long. 127° 19′ W. until 9 p. m. same date in lat. 34° 46′ N.; long. 131° 37′ W. this vessel was in a heavy dust area, wind NNW. to N. Area extended over 240 miles in SW.-NE. direction.

[1] Cf. Brooks, Chas. F. Warm, dry gale and dust storm in Northwest. Bulletin American Meteorological Society 12:112-13.
[2] Condensed from reports received by the Marine Division, U. S. Weather Bureau.

TORNADO STRIKES SWIFTLY-MOVING TRAIN

By R. J. McCLURG
[Weather Bureau, Moorhead, Minn.]

The crack train, Empire Builder, Seattle, Wash., to Chicago, Ill., May 27, 1931, was struck by a tornado nearly at a right angle as it was speeding at nearly a mile a minute about 5 miles east of Moorhead, Minn. The locomotive weighing 136 tons and the tender 94 tons, remained on the track. The engineer reports the cab windows as being torn out and that his goggles were blown away. Mr. McClurg's report follows.—ED.

A destructive tornado passed over part of extreme western Minnesota May 27, 1931, beginning about 4:15 p. m. The funnel-shaped cloud was first seen by farmers in the north part of Kurtz township about 10 miles south-southeast of the Moorhead Weather Bureau Office. It traveled an east-northeasterly course from first observation, crossing the Great Northern Railway track one-half mile northwest of Ruthruff siding, where it wrecked "The Empire Builder" at about 4:30 p. m. No observer can be found that knows the exact time this storm struck the train. From this point onward it took a north-northeasterly course for about 40 miles, where it destroyed everything in its path when it touched the ground. At times it lifted from the ground for several miles, only to swoop down to the ground again and carry on its destructive work. It evidently blew itself out between Gary and Fertile, Minn. It seems to be impossible to find anyone who knows at what time it was last seen. But it must have been traveling very rapidly for everyone who saw it spoke about its rapid movement. The tornado never came nearer than 4 miles to the United States Weather Bureau station at Moorhead.

The morning weather map of May 27 shows that Moorhead lay in a trough of low pressure, the center of which was over southeastern South Dakota. At the Moorhead station the following atmospheric conditions were recorded:

The barograph showed the air pressure was very erratic from 1:30 a. m., with a reading of 28.74 inches, until 2:00 p. m. at which time the reading was 28.64 inches. The pressure then fell rapidly to 28.47 inches by 4:30 p. m., then remained almost constant to 5:15 p. m. It then rose rapidly until 5:30 p. m., after which the rise was more gradual. Light rain began to fall at 4:04 p. m. with a heavy downpour from 4:16 p. m. to 4:37 p. m. Soft hail fell with the rain for 6 minutes. The total precipitation was 0.31 inch. The sun shone intermittently from 4:41 for the remainder of the evening. The wind velocity was from 6 to 13 miles an hour from 4 p. m. to 5:16 p. m., and was recorded at least once from the eight points of the compass. From 5:12 p. m. a southwest wind was increasing steadily, when at 5:30 p. m. it suddenly shifted to the northwest and reached a velocity of 33 miles an hour for 5 minutes. One mile was recorded at the rate of 36 miles per hour. The wind decreased steadily after 5:35 p. m.

Despite the untold damage done by this tornado of gigantic power, the marvelous thing about it is that only two lives were lost. When one car of the famed "Empire Builder" with its 117 passengers was lifted from the rails and carried through the air to be laid in a ditch 80 feet away, one man was hurled through a window and crushed beneath the coach when it fell on him. The other death resulted when a farm youth was pinned beneath the wreckage of his home and crushed to death.

The greatest manifestation of the force of this storm was shown by the wrecking of the train. Without a doubt, five of the coaches were torn loose from the engine and lifted bodily from the rails, the farthest one being hurled 80 feet away. The remaining eight coaches were probably pulled from the rails. The engine and tender remained on the rails intact. Fifty-seven passengers were injured by the impact and flying glass. It was due only to the fact that the heavy steel coaches were strong enough to resist the crash that more lives were not lost.

According to available reports, only 3 houses, 1 church, and 1 schoolhouse were demolished. The remainder of the damage was to other farm buildings, machinery, livestock, and trees.

On a tour of a portion of the path of the tornado the writer observed the usual freakish actions of the storm. At the Hatledal farm where one of the deaths took place the family are positive that two separate storms occurred. The first twister coming from the southwest destroyed the home, pinning Melvin Hatledal beneath a cement block in the southeast corner of the basement. After this twister passed on, the family escaped from the basement to the yard. In just a few minutes they observed a second twister, yellowish in color, approaching from the northwest. They expected it to strike them any second, but it veered to the east just before it reached them and wrecked a barn about 250 yards distant.

At the Fred Kudebeh farm a mile or so northwest of the Hatledal farm, Mr. Kudebeh was standing in his barn door watching the main twister passing about 200 yards to the east of him. All at once his own barn was lifted into the air leaving him standing unharmed. The barn was carried almost due west straight toward the farmhouse. One wall landed on the north side of the house, one wall on the south side, and one end on the east side of the house. The other end of the barn fell just a few feet west from the foundation. But the roof was carried over the house, through the tops of a grove of trees, some of which were 50 feet high, and fell in a field fully 200 yards from where the barn originally stood. Yet the house was not touched, except one corner of the porch which was struck by a flying timber.

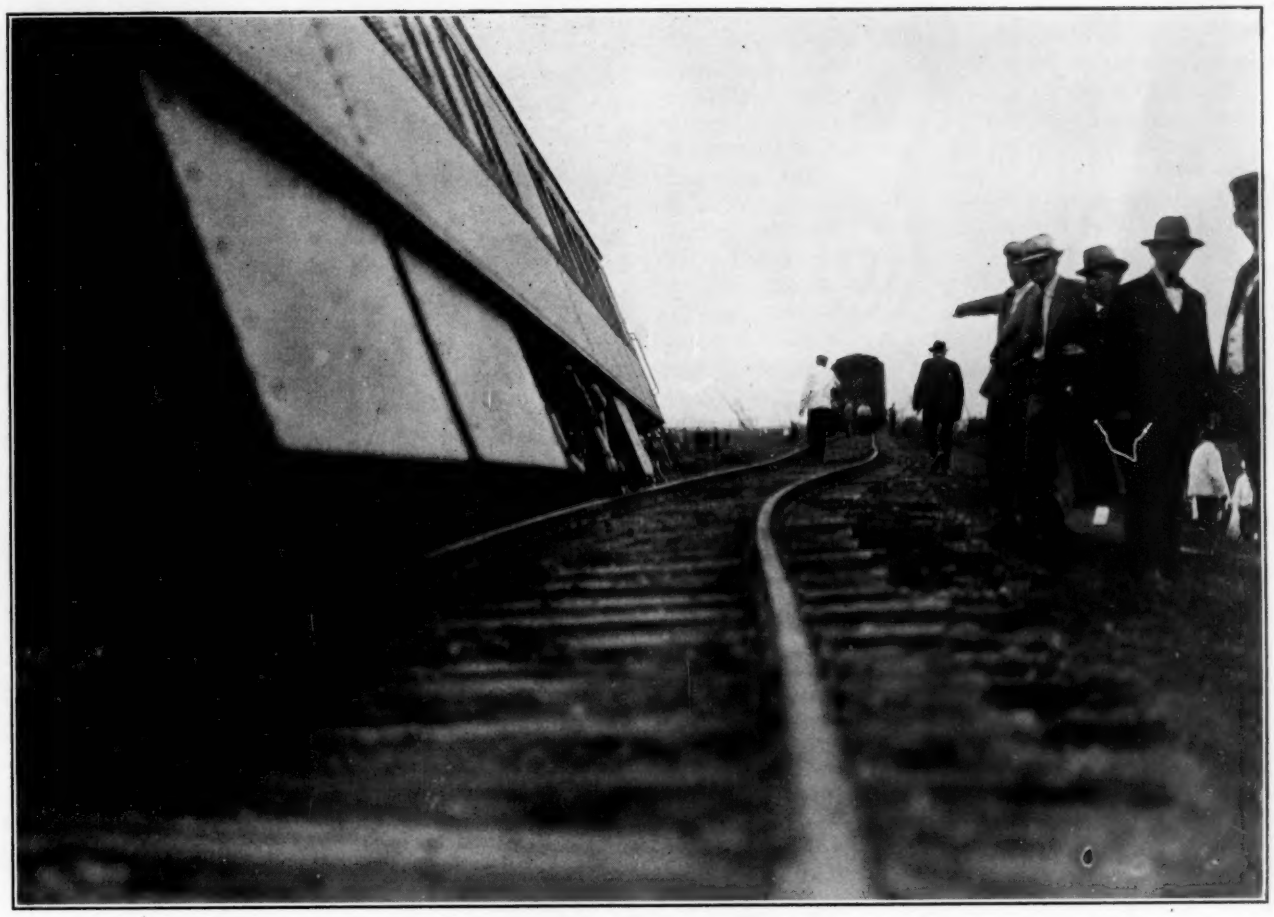
The main twister traveling due north at the time struck the Hanson farm where absolutely everything was demolished. House, barns, machine sheds, farm implements, dead animals and poultry were scattered all over the countryside. Farm implements of heavy iron and steel were twisted beyond recognition. Thirteen almost featherless chickens remained from a flock of 300. Trees were denuded of their limbs and leaves. The wreckage was carried to the northwest, while at another farm only about 300 yards west, wreckage was carried to the southeast.

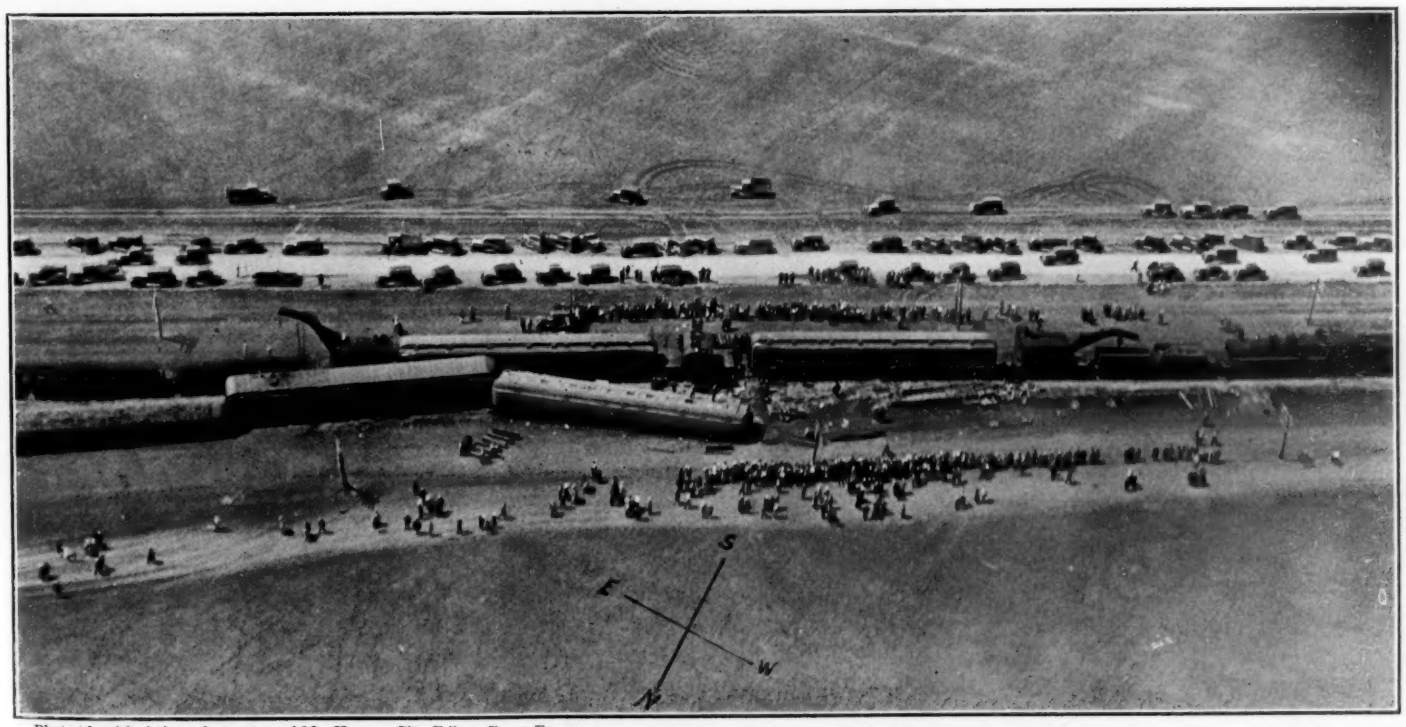
The writer saw straws driven into the bark of trees and at one place, saw a fresh straw driven in the wall of a house. At one place it was reported that a lace curtain was blown between the pane of glass and the sash with the glass remaining unbroken.

A conservative estimate of the damage was placed at $200,000. Growing crops not damaged very much where the storm did the damage to buildings, but reports from the higher lands to the southeast, where the soil is lighter, state that many fields will be reseeded because the wind blew away the planted crops.

The smaller picture of the two (fig. 1) was taken a few hours after the storm from the end of the fourth coach from the rear of the train. Eight coaches between the coach in the front of the picture and the engine in the background are lying in a ditch to the left of the picture. The aerial view was taken after the wrecker had placed two of the coaches back on the track.

(To face p. 198)





Photos furnished through courtesy of Mr. Hooper, City Editor, Fargo Forum

FIGURE. 1.—Upper, taken from end of fourth coach from rear of train; eight coaches are lying in a ditch to the left; lower, an aerial view of the wrecked cars after the wrecker had put two cars back on track

UNIV. OF MICH.

SUPPLEMENTAL REPORT BY R. J. M'CLURG

I had a conversation with the engineer, Mr. McKee, and the fireman, Mr. Klinfihn, these men gave an account of their observation of the tornado.

Mr. Klinfihn observed the storm at a distance, but did not see the funnel cloud. At the time the train was struck, he was busy at his work firing and was completely unaware of the impending disaster.

Mr. McKee, the engineer, first noticed the storm a mile or so away in the southwest, but did not see a funnel at that time. The train was traveling toward the southeast. He had seen many worse looking storms and did not give it much attention at first. The storm did not seem to move at all for several minutes, then moved slowly toward the train until it was about one-half mile away. It was then he noticed the funnel cloud and saw it take the top off a straw stack. The twister then darted forward and before he realized it was coming it had struck the train at almost right angles.

Mr. McKee thought the full force of the storm struck the engine; but due to the immense weight of the engine and the round shape, the engine and loaded tender were left standing on the rails. The remainder of the train of 12 coaches was derailed. Mr. McKee's glasses were pulled from his face by a force that he described as "a suction at his body." The fact that the coupling between the engine and the mail car was unbroken and still closed and locked after the wreck indicates that the front end of the mail car was lifted directly upward, permitting the coupling to separate without breaking. All the 12 cars remained coupled to each other, but some of the couplings were badly twisted by the derailment. All but one of the cars fell on their sides. This one exception was a car caught between two coaches and could not fall over. On page 2 of my report of June 2, 1931, I stated that five coaches were lifted from the tracks and the other 8 were pulled from it. It should read "Five coaches were lifted from the tracks and the other 7 were pulled from the track."

The conductor stated that practically all of the windows of the coaches were closed because a light rain was falling; the car ventilators were open. The greater number of the windows were not broken by the sudden lessening of the outside pressure. They had to be broken by trainmen and others to let the imprisoned passengers escape.

The following is a list of the weights of the cars and engine:

	Tons		Tons
Engine	136	Diner	89
Tender, loaded	94	Pullman	64
Mail car	70	Do	64
Baggage car	72	Do	64
Smoking car	59	Do	64
Day coach	83	Do	61
Tourist	76	Club car	85

TABLE FOR FACILITATING COMPUTATION OF POTENTIAL TEMPERATURE

By J. C. BALLARD
[Aerological Division, Weather Bureau, Washington, D. C.]

The following table of factors has been found to be very useful in the computation of potential temperatures. Where P = pressure in millibars, the table gives values $K=\left(\frac{1000}{P}\right)^{0.288}$ for intervals of one millibar from 1,049 to 40 millibars of pressure. For lower pressure the computation must be made by logarithms.

The factor $\left(\frac{1000}{P}\right)^{0.288}$ is the pressure factor in the formula

$$\Theta = T\left(\frac{1000}{P}\right)^{0.288}$$

Where θ = potential temperature in °A, T = actual temperature in °A and P = pressure in millibars. Hence, it is evident that the potential temperature is computed merely by multiplying the actual temperature in °A by the proper factor (K) found in the table.

Computations have been made for whole millibars, and where pressure is used to tenths of millibars, linear interpolation for tenths has been found to be sufficiently accurate for ordinary purposes. Several cases have been tested for error in the factor due to linear interpolation and in no case has an error as much as 0.0003 been found. An error of 0.0003 in the factor would never produce an error of more than 0.1° in potential temperature, or one well within the range of accuracy of the observed temperature and pressure. The accompanying graph (fig. 1) is the curve $Y=\left(\frac{1000}{P}\right)^{0.288}$. It is apparent that for low pressures where differences in the values of the function are relatively great for small differences in pressure, the error due to interpolating linearly between two pressures for intermediate values of the function would be relatively small.

If it is desired, tables of interpolated parts can be prepared which will assist somewhat in the interpolation.[1]

[1] Such tables are available in Publication No. 245 of the Carnegie Institution, 1918, by H. B. Hedrick.

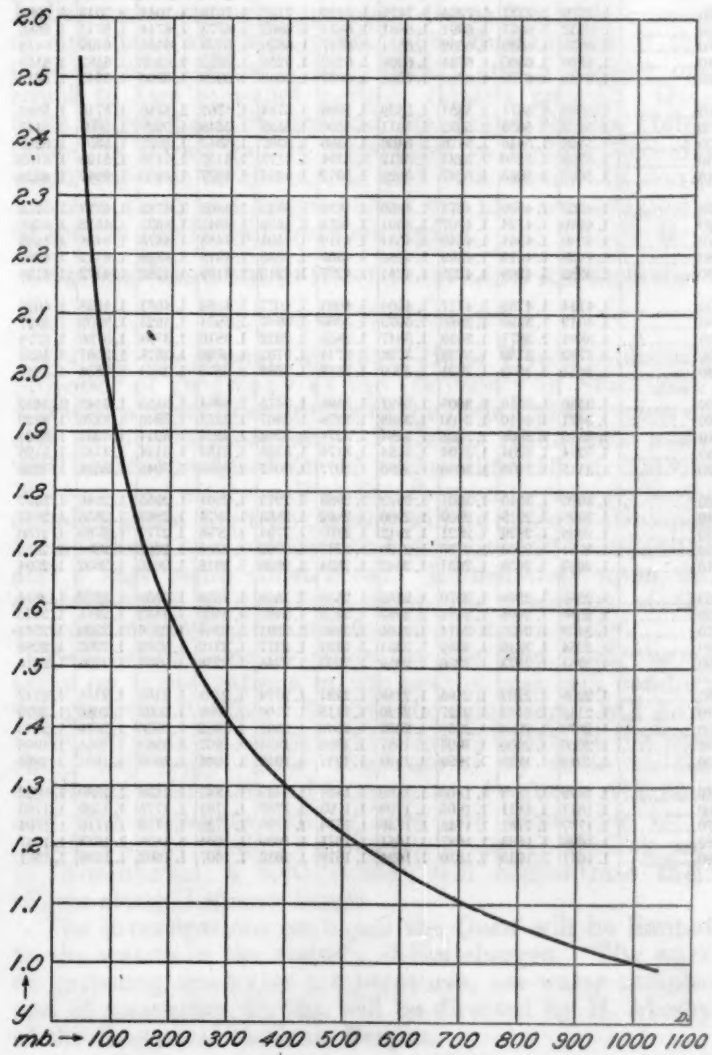


FIGURE 1.—Graph of the curve $Y=\left(\frac{1000}{P}\right)^{0.288}$

For rapid and approximate computation of potential temperatures it may be found convenient to prepare a large graph similar to Figure 1, by which approximate values of the pressure factor can be easily obtained. The Adiabatic Chart gives potential temperatures directly for any given temperature and pressure within a limited range, and a proper extention of this chart would make it possible to read off potential temperatures for any given temperature and pressure with no computation whatever.

The paper Tables of the 0.288 th. powers by Dr. T. N. Doerr of Vienna, published in the Quarterly Journal of the Royal Meteorological Society, Vol. 47, 1921, pages 196–202, was used in the preparation of the accompanying table. The values were obtained by dividing $(1000)^{0.288}$ by $(P)^{0.288}$ where P varied from 50 to 1,049, inclusive. The values for pressures from 40 to 49 millibars, inclusive, were computed by logarithms.

Potential temperature factor (K) for various pressures in mb.

[Temperatures in absolute degrees multiplied by K=potential temperatures]

Mb.	0	1	2	3	4	5	6	7	8	9
40	2.5270	2.5091	2.4917	2.4749	2.4586	2.4428	2.4273	2.4124	2.3977	2.3834
50	2.3697	2.3562	2.3431	2.3303	2.3178	2.3056	2.2936	2.2820	2.2706	2.2594
60	2.2485	2.2378	2.2274	2.2171	2.2071	2.1973	2.1876	2.1782	2.1689	2.1598
70	2.1509	2.1421	2.1335	2.1250	2.1167	2.1086	2.1005	2.0926	2.0849	2.0772
80	2.0697	2.0623	2.0550	2.0479	2.0408	2.0339	2.0271	2.0203	2.0137	2.0071
90	2.0007	1.9943	1.9880	1.9819	1.9758	1.9698	1.9638	1.9580	1.9522	1.9465
100	1.9409	1.9354	1.9298	1.9244	1.9191	1.9138	1.9086	1.9034	1.8983	1.8933
110	1.8883	1.8834	1.8786	1.8738	1.8690	1.8643	1.8597	1.8551	1.8505	1.8460
120	1.8416	1.8372	1.8328	1.8285	1.8243	1.8201	1.8159	1.8118	1.8077	1.8036
130	1.7996	1.7956	1.7917	1.7878	1.7840	1.7802	1.7764	1.7726	1.7689	1.7652
140	1.7616	1.7580	1.7545	1.7509	1.7474	1.7439	1.7405	1.7370	1.7336	1.7303
150	1.7270	1.7237	1.7204	1.7171	1.7139	1.7107	1.7076	1.7044	1.7013	1.6982
160	1.6952	1.6921	1.6891	1.6861	1.6831	1.6802	1.6773	1.6744	1.6715	1.6686
170	1.6658	1.6630	1.6602	1.6574	1.6547	1.6520	1.6493	1.6466	1.6439	1.6412
180	1.6386	1.6360	1.6334	1.6308	1.6283	1.6257	1.6232	1.6207	1.6182	1.6157
190	1.6133	1.6109	1.6085	1.6061	1.6037	1.6013	1.5989	1.5966	1.5943	1.5919
200	1.5896	1.5874	1.5851	1.5829	1.5806	1.5784	1.5762	1.5740	1.5718	1.5696
210	1.5675	1.5653	1.5632	1.5611	1.5590	1.5569	1.5548	1.5527	1.5507	1.5487
220	1.5466	1.5446	1.5426	1.5406	1.5386	1.5367	1.5347	1.5327	1.5307	1.5288
230	1.5269	1.5250	1.5231	1.5212	1.5194	1.5175	1.5157	1.5138	1.5120	1.5102
240	1.5083	1.5065	1.5047	1.5029	1.5012	1.4994	1.4977	1.4959	1.4942	1.4924
250	1.4907	1.4890	1.4873	1.4856	1.4839	1.4822	1.4805	1.4789	1.4773	1.4756
260	1.4740	1.4724	1.4707	1.4691	1.4675	1.4659	1.4643	1.4627	1.4612	1.4596
270	1.4580	1.4564	1.4549	1.4534	1.4519	1.4504	1.4488	1.4473	1.4458	1.4443
280	1.4428	1.4414	1.4399	1.4384	1.4369	1.4355	1.4340	1.4326	1.4312	1.4298
290	1.4283	1.4269	1.4255	1.4241	1.4227	1.4213	1.4199	1.4186	1.4172	1.4158
300	1.4144	1.4130	1.4117	1.4104	1.4091	1.4077	1.4064	1.4051	1.4038	1.4025
310	1.4012	1.3999	1.3986	1.3973	1.3960	1.3947	1.3934	1.3921	1.3909	1.3897
320	1.3884	1.3871	1.3859	1.3847	1.3835	1.3822	1.3810	1.3798	1.3786	1.3774
330	1.3762	1.3750	1.3738	1.3726	1.3714	1.3702	1.3690	1.3678	1.3667	1.3655
340	1.3644	1.3632	1.3621	1.3609	1.3598	1.3586	1.3575	1.3564	1.3553	1.3541
350	1.3530	1.3519	1.3508	1.3497	1.3486	1.3475	1.3464	1.3453	1.3443	1.3432
360	1.3421	1.3410	1.3400	1.3389	1.3378	1.3367	1.3357	1.3346	1.3336	1.3325
370	1.3315	1.3305	1.3295	1.3284	1.3274	1.3264	1.3254	1.3244	1.3234	1.3224
380	1.3214	1.3204	1.3194	1.3184	1.3174	1.3164	1.3154	1.3144	1.3135	1.3125
390	1.3115	1.3105	1.3096	1.3086	1.3077	1.3067	1.3058	1.3048	1.3039	1.3029
400	1.3020	1.3010	1.3001	1.2992	1.2983	1.2973	1.2964	1.2955	1.2946	1.2937
410	1.2928	1.2919	1.2909	1.2900	1.2892	1.2883	1.2874	1.2865	1.2856	1.2847
420	1.2838	1.2829	1.2821	1.2812	1.2803	1.2794	1.2786	1.2777	1.2769	1.2760
430	1.2751	1.2743	1.2735	1.2726	1.2717	1.2709	1.2701	1.2692	1.2684	1.2675
440	1.2667	1.2659	1.2651	1.2642	1.2634	1.2626	1.2618	1.2610	1.2602	1.2594
450	1.2586	1.2578	1.2570	1.2562	1.2554	1.2546	1.2538	1.2530	1.2522	1.2514
460	1.2506	1.2498	1.2491	1.2483	1.2475	1.2467	1.2460	1.2452	1.2444	1.2436
470	1.2429	1.2421	1.2414	1.2406	1.2399	1.2391	1.2384	1.2376	1.2369	1.2361
480	1.2354	1.2346	1.2339	1.2331	1.2324	1.2317	1.2310	1.2302	1.2295	1.2288
490	1.2281	1.2273	1.2266	1.2259	1.2252	1.2245	1.2238	1.2231	1.2224	1.2216
500	1.2209	1.2202	1.2195	1.2188	1.2181	1.2174	1.2168	1.2161	1.2154	1.2147
510	1.2140	1.2133	1.2127	1.2120	1.2113	1.2106	1.2099	1.2093	1.2086	1.2079
520	1.2072	1.2066	1.2059	1.2052	1.2045	1.2039	1.2032	1.2026	1.2019	1.2013
530	1.2006	1.2000	1.1993	1.1987	1.1980	1.1974	1.1967	1.1961	1.1955	1.1948
540	1.1942	1.1935	1.1929	1.1923	1.1917	1.1910	1.1904	1.1898	1.1891	1.1885
550	1.1879	1.1872	1.1866	1.1860	1.1854	1.1848	1.1842	1.1836	1.1830	1.1823
560	1.1817	1.1811	1.1805	1.1799	1.1793	1.1787	1.1781	1.1775	1.1769	1.1763
570	1.1757	1.1751	1.1745	1.1739	1.1734	1.1728	1.1722	1.1716	1.1710	1.1704
580	1.1699	1.1693	1.1687	1.1681	1.1675	1.1669	1.1664	1.1658	1.1653	1.1647
590	1.1641	1.1635	1.1630	1.1624	1.1618	1.1613	1.1607	1.1602	1.1596	1.1591

Potential temperature factor (K) for various pressures in mb.—Contd.

Mb.	0	1	2	3	4	5	6	7	8	9
600	1.1585	1.1579	1.1574	1.1568	1.1563	1.1557	1.1552	1.1546	1.1541	1.1535
610	1.1530	1.1524	1.1519	1.1513	1.1508	1.1502	1.1497	1.1492	1.1487	1.1482
620	1.1476	1.1471	1.1465	1.1460	1.1455	1.1449	1.1444	1.1439	1.1434	1.1428
630	1.1423	1.1418	1.1413	1.1408	1.1403	1.1398	1.1393	1.1387	1.1382	1.1377
640	1.1372	1.1366	1.1361	1.1356	1.1351	1.1346	1.1341	1.1336	1.1331	1.1326
650	1.1321	1.1316	1.1311	1.1306	1.1301	1.1296	1.1291	1.1286	1.1281	1.1276
660	1.1271	1.1266	1.1261	1.1256	1.1252	1.1247	1.1242	1.1237	1.1232	1.1228
670	1.1223	1.1218	1.1213	1.1208	1.1203	1.1198	1.1194	1.1189	1.1184	1.1180
680	1.1175	1.1170	1.1165	1.1160	1.1156	1.1151	1.1146	1.1142	1.1137	1.1133
690	1.1128	1.1123	1.1118	1.1114	1.1109	1.1105	1.1100	1.1096	1.1091	1.1087
700	1.1082	1.1078	1.1073	1.1069	1.1064	1.1060	1.1055	1.1051	1.1046	1.1042
710	1.1037	1.1033	1.1028	1.1023	1.1019	1.1014	1.1010	1.1005	1.1001	1.0996
720	1.0992	1.0988	1.0983	1.0979	1.0975	1.0970	1.0966	1.0962	1.0957	1.0953
730	1.0949	1.0944	1.0940	1.0935	1.0931	1.0927	1.0923	1.0918	1.0914	1.0910
740	1.0906	1.0901	1.0897	1.0893	1.0889	1.0884	1.0880	1.0876	1.0872	1.0868
750	1.0864	1.0859	1.0855	1.0851	1.0847	1.0843	1.0839	1.0834	1.0830	1.0826
760	1.0822	1.0818	1.0814	1.0810	1.0806	1.0802	1.0798	1.0794	1.0790	1.0786
770	1.0782	1.0778	1.0774	1.0770	1.0766	1.0762	1.0758	1.0754	1.0750	1.0746
780	1.0742	1.0738	1.0734	1.0730	1.0726	1.0722	1.0718	1.0714	1.0710	1.0706
790	1.0702	1.0698	1.0695	1.0691	1.0687	1.0683	1.0679	1.0675	1.0671	1.0668
800	1.0664	1.0660	1.0656	1.0652	1.0648	1.0644	1.0641	1.0637	1.0633	1.0629
810	1.0626	1.0622	1.0618	1.0615	1.0611	1.0607	1.0603	1.0599	1.0596	1.0592
820	1.0588	1.0584	1.0581	1.0577	1.0573	1.0570	1.0566	1.0563	1.0559	1.0555
830	1.0551	1.0548	1.0544	1.0541	1.0537	1.0533	1.0529	1.0526	1.0522	1.0519
840	1.0515	1.0512	1.0508	1.0505	1.0501	1.0497	1.0493	1.0490	1.0486	1.0483
850	1.0479	1.0476	1.0472	1.0469	1.0465	1.0462	1.0458	1.0455	1.0451	1.0448
860	1.0444	1.0441	1.0437	1.0433	1.0430	1.0427	1.0423	1.0420	1.0416	1.0413
870	1.0409	1.0406	1.0402	1.0399	1.0396	1.0392	1.0389	1.0385	1.0382	1.0378
880	1.0375	1.0372	1.0368	1.0365	1.0362	1.0358	1.0355	1.0351	1.0348	1.0344
890	1.0341	1.0338	1.0334	1.0331	1.0327	1.0324	1.0321	1.0318	1.0315	1.0311
900	1.0308	1.0305	1.0302	1.0298	1.0295	1.0292	1.0288	1.0285	1.0282	1.0279
910	1.0275	1.0272	1.0269	1.0266	1.0262	1.0259	1.0256	1.0253	1.0249	1.0246
920	1.0243	1.0240	1.0236	1.0233	1.0230	1.0227	1.0224	1.0221	1.0218	1.0214
930	1.0211	1.0208	1.0205	1.0202	1.0198	1.0195	1.0192	1.0189	1.0186	1.0183
940	1.0180	1.0177	1.0173	1.0170	1.0167	1.0164	1.0161	1.0158	1.0155	1.0152
950	1.0149	1.0146	1.0143	1.0140	1.0137	1.0133	1.0130	1.0127	1.0124	1.0121
960	1.0118	1.0115	1.0112	1.0109	1.0106	1.0103	1.0100	1.0097	1.0094	1.0091
970	1.0088	1.0085	1.0082	1.0079	1.0076	1.0073	1.0070	1.0067	1.0064	1.0061
980	1.0058	1.0055	1.0052	1.0049	1.0047	1.0044	1.0041	1.0038	1.0035	1.0032
990	1.0029	1.0026	1.0023	1.0020	1.0017	1.0014	1.0012	1.0009	1.0006	1.0003
1000	1.0000	0.9997	0.9994	0.9991	0.9989	0.9986	0.9983	0.9980	0.9977	0.9974
1010	0.9971	0.9969	0.9966	0.9963	0.9960	0.9957	0.9954	0.9952	0.9949	0.9946
1020	0.9943	0.9940	0.9938	0.9935	0.9932	0.9929	0.9926	0.9924	0.9921	0.9918
1030	0.9915	0.9912	0.9910	0.9907	0.9904	0.9901	0.9899	0.9896	0.9893	0.9890
1040	0.9888	0.9885	0.9882	0.9879	0.9877	0.9874	0.9871	0.9869	0.9866	0.9863

RECOVERY OF SOUNDING-BALLOON METEOROGRAPH AFTER THREE YEARS AND THREE MONTHS

By L. T. SAMUELS

What is believed to be a long-period record for the return of a balloon meteorograph occurred recently when a Fergusson meteorograph which was sent up from the Weather Bureau office, Los Angeles, Calif., on December 31, 1927, at 4:58 a. m. and found on April 12, 1931, approximately 125 miles to the southeast. The official in charge at Los Angeles reports, "The meteorograph was nearly covered with trash and the basket in which the meteorograph was tied when released was not found. The remains of the balloon were near the spot where the instrument was lying. The instructions that were tied to the instrument were still with it but they were only partly legible."

It was found that the smoked record was entirely legible and the computation of the ascent and descent are in strikingly close agreement. The record indicates a maximum altitude of 14,196 meters, although the stratosphere was not reached. The temperature decreased from 11.1° C. at the surface to −74.1° C. at the maximum altitude.

TEN YEARS OF SCIENTIFIC AIRPLANE ASCENTS IN HOLLAND

By Dr. H. G. CANNEGIETER

[Published in Zeitschrift für Angewandte Meteorologie. Das Wetter, Heft 10, Oktober, 1930. Abstracted by J. C. Ballard, Aerological Division, Weather Bureau, Washington, D. C.]

Ten years of upper-air observations by airplanes were completed at Soesterberg, Holland, in 1929, and eight years of similar observations at De Kooij, Holland. A good summary of the regularity of this service is shown by the accompanying charts.

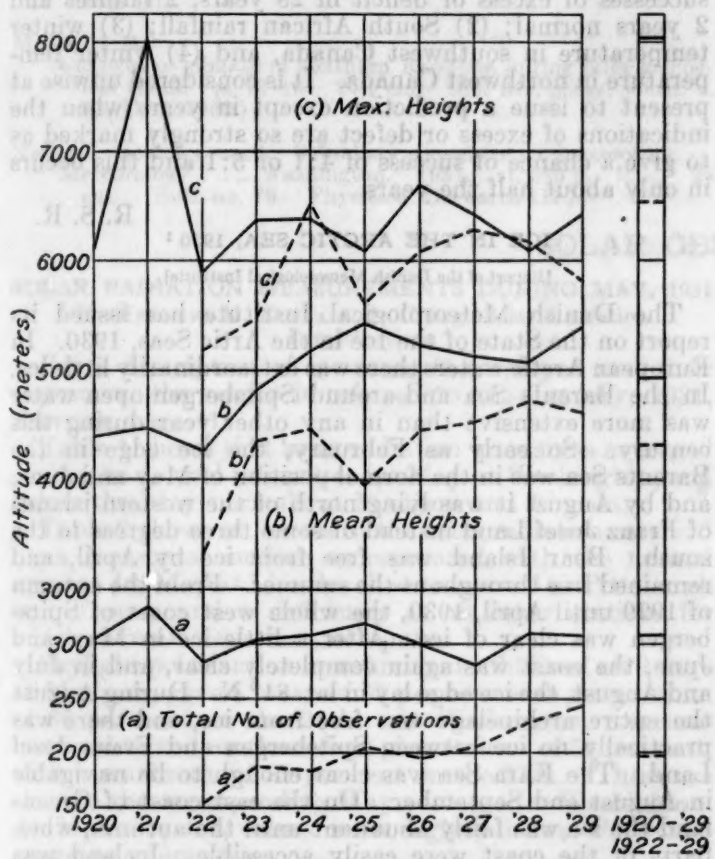


FIGURE 1.—Graph showing the total number of observations per year at Soesterberg, and the mean altitude attained

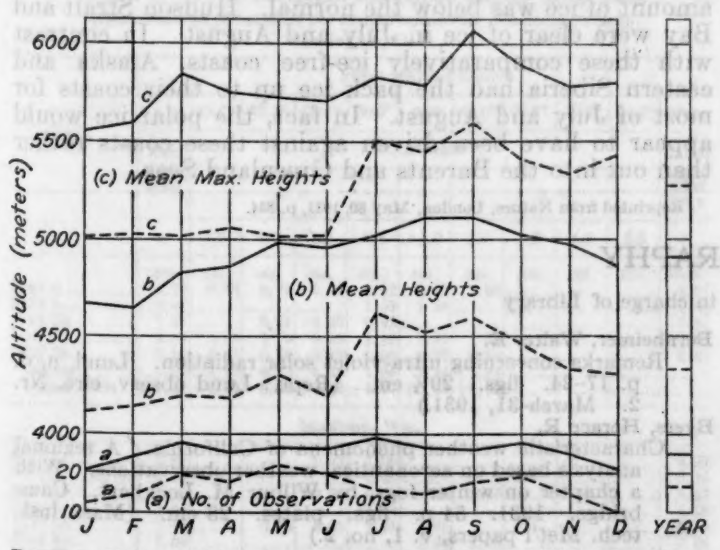


FIGURE 2.—Meteorological airplane observations in Holland: Solid line, Soesterberg, 1920-1929; dashed line, De Kooij, 1922-1929

It will be noted (fig. 1) that at Soesterberg the total number of observations per year averaged over 300 for the 10-year period and the mean altitude attained was nearly 5 km.

Figure 2 shows the monthly distribution. The least number of observations per month occurred in December and January, but at Soesterberg the average number of observations during these months did not fall below 20.

From 75 to 80 per cent of the observations were made before 10 a. m. and the remainder at later times during the day.

Note by abstractor.—It is interesting to compare these results with those obtained by kites and captive balloons in the United States. The average number of days per year (294) of kite and captive balloon observations at the five aerological stations of the Weather Bureau compares very favorably with these results. However, the mean altitude attained at these stations over the 9 year period 1922–1930, inclusive, is less than 2,700 meters above sea level.

S. HANZLIK ON ATMOSPHERIC PRESSURE EFFECT OF THE SUN-SPOT PERIOD

[Reprinted from Science Abstracts No. 754]

Part I. Yearly Means. S. Hanzlik. Gerlands Beitr. z. Geophys. 28. 1-3. pp. 114–125, 1930.—The difference of mean air pressure for the three years of sun-spot minimum and the succeeding three years of sun-spot maximum for stations over the whole globe is set out in a chart for each of the last five sun-spot periods, 1866–1919. Four different areas are indicated according to the sign of the effect. Areas of positive effect lie in the Indian monsoon region, pressure decreasing with increase of sun spots and vice versa. The fluctuations of this positive effect show a long period and a shorter one equal to two sun-spot periods (Hale's period). Over belts in middle latitudes and the Arctic regions Hale's period is shown but it is positive in middle latitudes when negative in the Arctic and vice versa. In South America there is a longer period but in a sense opposite to that in the Indian monsoon region. R. S. R.

SWEDISH-NORWEGIAN NORTHEASTLAND EXPEDITION

By LEONARD R. SCHNEIDER

During the summer of 1931, Hans W:son Ahlmann, professor of geography at the University of Stockholm, will lead a party of scientists to the little known region on and about Northeastland. Professor Ahlmann's party will board the *Quest* on or about June 15 at Narvik, Norway, and after a call at Spitzbergen to take on board supplies and a dog team, a stop will be made in Hinlopen Strait where, on Northeastland, supplies will be unloaded and a base camp constructed. Immediately upon the establishment of the base camp the members of the expedition will begin a summer of intensive study.

Two groups, one to study on the land, and one to carry on investigations in the nearby seas will conduct the major activities. Briefly, the land party will have as its work the following: (1) Meteorologists at the base camp will report their observations by radio to the *Quest* and to Sweden and Norway, (2) Professor Ahlmann and two assistants will go onto the inland ice for a month's study, and (3) geologists under O. Kulling and L. Rosenbaum, a topographer, will concentrate their efforts along Hinlopen Strait.

The investigations on board the *Quest* will be limited to the waters in the vicinity of Spitzbergen. The work of gathering sea-water temperatures, sea-water samples and of measuring depths, will be directed by H. Mosby of the Geofysical Institut, Bergen.

In concluding this summary of the projected work of the expedition it may be of interest to point out that the winter 1930–31 on Spitzbergen was unusually mild. In fact, at the end of March there was no ice in the expansive Icefjord and none on the sea in the immediate coastal region.

UPWELLING COLD WATER ON THE COAST OF NEW JERSEY

By CHARLES F. BROOKS

[Clark University, Worcester, Mass.]

On Sunday, July 7, 1929, while people were sweltering in New York City, others who had sought the Jersey coast were actually wearing coats. Mr. Henry B. Newhall reports that a friend of his, who has a summer home at Manasquan, was fishing in a lined fishing or hunting coat and was glad to have it on, but, he said that only a few thousand feet away from the shore it was pretty hot. They had had a strong S. to SE. wind for two or three days. The water, as somebody told him, as reported by the coast guards, was at unbelievably low temperatures—in the 40s.

In response to a request for the official temperatures, Assistant Commandant B. S. Chiswell, supplied the sea temperature readings for the first 15 days in July at Manasquan, N. J. They run as follows, beginning with the 1st; 47, 48, 52, 50, 48, 47, 46 (on the 7th), 50, 55, 60, 64, 68, 68, 70, 70 degrees. The sea temperature at Atlantic City from July 1 to 11, inclusive, as reported by Walcott L. Day, meteorologist, United States Weather Bureau, ranged from 62° to 67° and was 64° F. on the 7th. Atlantic City air temperatures that day ranged from 67° to 76° and on the preceding day 68° to 76° F. Winds on the 7th were S. to SW., 17 to 29 miles an hour. The wind on the 6th was of the same direction but averaged 16.4. Rather strong southerly winds prevailed also on the 4th and 5th, with average velocities of 18 and 20 miles an hour and maxima of 29 and 30, and an extreme 5-minute velocity of 32 miles.

On this occasion the S. to SW. winds which were onshore for Atlantic City were off-shore for the coast of New Jersey farther north. The tendency of wind to blow water in the direction 45 degrees to the right of its own direction in the northern hemisphere would favor a rapid removal of surface waters eastward and the consequent upwelling along the coast.

In the MONTHLY WEATHER REVIEW for June, July, and August, 1920 (48: 352–353, 424, 477–478), there are notes on a similar occurrence, attending a usual frequency of off-shore winds that summer.

G. T. WALKER ON SEASONAL FORESHADOWING

[Reprinted from Science Abstracts No. 757]

Roy. Meteorolog. Soc., J. 56, pp. 359–362; Disc., 362–364, October, 1930.—The paper contains results obtained by the author and E. W. Bliss in applying various relationships in different parts of the world to predict abnormal seasons. The application has been made for: (1) Summer monsoon rainfall in Australia which gave 24 successes of excess or deficit in 28 years, 2 failures and 2 years normal; (2) South African rainfall; (3) winter temperature in southwest Canada, and (4) winter temperature in northwest Canada. It is considered unwise at present to issue a prediction except in years when the indications of excess or defect are so strongly marked as to give a chance of success of 4:1 or 5:1 and this occurs in only about half the years.

R. S. R.

ICE IN THE ARCTIC SEA, 1930 [1]

[Report of the Danish Meteorological Institute]

The Danish Meteorological Institute has issued its report on the State of the Ice in the Artic Seas, 1930. In European Arctic waters there was extraordinarily little ice. In the Barents Sea and around Spitsbergen open water was more extensive than in any other year during this century. So early as February, the ice edge in the Barents Sea was in the normal position of May and June, and by August it was lying north of the western islands of Franz Josef Land instead of some three degrees to the south. Bear Island was free from ice by April, and remained free throughout the summer. From the autumn of 1929 until April, 1930, the whole west coast of Spitsbergen was clear of ice. After a little ice in May and June, the coast was again completely clear, and in July and August, the ice edge lay in lat. 81° N. During August the entire archipelago was free from ice, and there was practically no ice between Spitsbergen and Franz Josef Land. The Kara Sea was clear enough to be navigable in August and September. On the east coast of Greenland the ice was fairly abundant until the autumn, when parts of the coast were easily accessible. Iceland was almost ice free throughout the year. In Davis Strait the amount of ice was below the normal. Hudson Strait and Bay were clear of ice in July and August. In contrast with these comparatively ice-free coasts, Alaska and eastern Siberia had the pack ice up to their coasts for most of July and August. In fact, the polar ice would appear to have been driven against these coasts rather than out into the Barents and Greenland Seas.

[1] Reprinted from Nature, London, May 30, 1931, p. 834.

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RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING MAY, 1931

By HERBERT H. KIMBALL, In Charge Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January, 1931, REVIEW, page 41.

Table 1 shows that solar radiation intensities averaged above the normal intensities for May at Washington, and below the May normals at Madison and Lincoln.

Table 2 shows an excess in the total radiation received on a horizontal surface as compared with the normal amount for May at Lincoln, close to normal at Pittsburgh and Fresno, and a deficiency at all other stations for which normals have been computed.

Skylight polarization measurements obtained on 9 days at Madison, gave a mean of 53 per cent with a maximum of 60 per cent on the 25th. At Washington, measurements obtained on three days give a mean of 56 per cent, with a maximum of 58 per cent on the 27th. These are close to the corresponding May averages for Washington. At Madison, the values were slightly below the corresponding averages.

TABLE 1.—*Solar radiation intensities during May, 1931*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 4	4.75	0.68	0.75	0.94	1.12	1.49	1.05				4.57
May 9	9.47				1.03	1.29					8.48
May 22	7.57		0.51	0.65	0.92						7.87
May 27	7.04	0.66	0.79	0.95	1.18	1.31	1.05				6.50
May 28	9.14	0.61	0.74	0.88	1.05	1.28	0.94				8.81
Means		0.65	0.70	0.86	1.06	1.34	1.01				
Departures		+0.01	−0.01	+0.04	+0.07	+0.05	+0.02				
Madison, Wis.											
May 1	3.81			0.73	1.00						4.37
May 2	4.75				1.01						5.16
May 4	2.36			0.77	0.98	1.34	0.95				4.17
May 5	5.16				1.04						5.16
May 13	7.04		0.78	0.91	1.11	1.46					6.76
May 15	7.04					1.34	1.08				7.04
May 23	5.79	0.69	0.79	0.94	1.14	1.40					5.16
May 25	8.18	0.72	0.85	0.98	1.15	1.44					7.29
May 26	7.29				0.93						9.14
Means		(0.70)	0.81	0.87	1.04	1.40	(1.02)				
Departures		−0.07	−0.06	−0.06	−0.06	+0.04	−0.01				

TABLE 1.—*Solar radiation intensities during May, 1931*—Contd.

[Gram-calories per minute per square centimeter of normal surface]

Lincoln, Nebr.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 2	4.37					1.40	1.13	0.93	0.78	0.66	4.57
May 3	4.57	0.57	0.69	0.83	1.03	1.45					4.75
May 14	7.29			0.89	1.17	1.38	1.16	0.95	0.80	0.69	7.57
May 15	7.87	0.68	0.77	0.91	1.12	1.36					9.47
May 20	3.81		0.87	1.01	1.19	1.42					3.81
May 22	5.16		0.82	0.97	1.10						5.79
May 23	11.81						1.04				6.50
May 25	8.81		0.43	0.64	0.87	1.19	0.86	0.64	0.48		10.21
Means		(0.62)	0.72	0.88	1.08	1.37	1.05	0.84	0.69	(0.68)	
Departures		−0.06	−0.08	−0.05	−0.04	−0.01	−0.06	−0.09	−0.10	±0.00	

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram calories per square centimeter]

Week beginning	Average daily totals: Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Pittsburgh	Gainesville	Fresno	La Jolla	Miami	New Orleans
1931	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 30	504	534	553	434	437	488	479	523	653	302	208	291
May 7	339	276	344	210	213	721	314	601	595	368	572	393
May 14	441	392	549	388	407	653	433	659	708	403	617	327
May 21	479	516	653	488	221	623	456	621	663	431	633	393
May 28	546	412	557	385	415	596	451	566	685	416	596	440
	Departures from weekly normals											
Apr. 30	+46	+77	+79	+69	+71	−81	+63	−82	+29	−105		
May 7	−116	−179	−136	−164	−149	+107	−94	−52	−48	−60		
May 14	−18	−72	+39	+8	+47	−1	+35	−7	+48	−30		
May 21	−9	+30	+121	+82	−159	−55	+12	−10	−27	−18		
May 28	+35	−79	+32	−38	+15	−87	−3	−30	−19	−46		
Accumulated departures on June 3, 1931	+145	−3,682	+266	−889	−679	+1,044	−423	−506	+119	−2,576		

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1931	h m	°	°	°			
May 1 (Naval Observatory)	11 21	+60.0	273.2	+15.0		46	46
May 2 (Naval Observatory)	14 10	+72.0	270.5	+18.0	46		46
May 3 (Naval Observatory)	11 18	−52.0	134.8	+27.0	3		
		−38.0	148.8	+2.0	19		22
May 4 (Naval Observatory)	11 16	+60.5	234.1	−10.0		46	46
May 5 (Naval Observatory)	10 52	−7.5	153.1	+10.5	22		22
May 6 (Naval Observatory)	10 49	−17.0	130.4	−2.0	3		
		+9.0	156.4	+11.0	31		34
May 7 (Naval Observatory)	13 16	−70.0	62.9	+5.0		123	
		+22.0	154.9	+13.0	15		138
May 8 (Naval Observatory)	10 48	−61.0	60.0	+5.0		108	
		−49.0	72.0	+2.0	6		114
May 9 (Naval Observatory)	10 59	−50.0	57.7	+7.5		185	185
May 10 (Naval Observatory)	10 59	−37.5	57.0	+9.0		216	
		−1.0	93.5	+34.0	9		
		+40.0	134.5	+1.5		123	348
May 11 (Naval Observatory)	11 27	−21.0	60.0	+8.5		154	
		+55.0	136.0	+1.5		77	231
May 12 (Mount Wilson)	11 30	−8.0	59.7	+9.0		121	
		−7.0	60.7	+7.0	133		
		+41.0	108.7	+5.0		5	
		+71.0	138.7	−1.0	161		420
May 13 (Mount Wilson)	9 40	+4.0	59.4	+8.0		99	
		+4.0	59.4	+7.0	124		
		+55.0	110.4	+5.0		6	
		+87.0	142.4	+0.5	51		280
May 14 (Naval Observatory)	11 5	+20.0	61.5	+10.0		139	139
May 15 (Naval Observatory)	12 22	−71.0	316.6	+8.5	31		
		−60.0	327.6	−17.5	31		
		−13.0	14.6	−6.0	3		
		+34.0	61.6	+10.5		216	281
May 16 (Naval Observatory)	10 45	−65.0	310.2	+11.0		6	
		−50.0	325.2	−17.5		170	
		−2.5	12.7	+11.0	3		
		+47.0	62.2	+10.5		185	364
May 17 (Naval Observatory)	10 55	−60.5	301.4	+15.0	3		
		−37.5	324.4	−15.0		108	
		−9.5	352.4	+14.0	3		
		+60.0	61.9	+11.0		77	191
May 18 (Naval Observatory)	10 54	−23.0	325.7	−16.0		201	
		−2.5	346.2	+11.0	15		
		+73.0	61.7	+12.0		93	309
May 19 (Naval Observatory)	10 55	−10.0	325.5	−15.0		262	
		+14.0	349.5	+11.0	6		268
May 20 (Naval Observatory)	11 5	+2.5	324.6	−15.5		401	
		+62.0	24.1	+17.5	3		404
May 21 (Naval Observatory)	13 12	−60.0	247.8	+12.0		15	
		+11.0	318.8	−5.0	6		
		+18.0	325.8	−15.0		370	391
May 22 (Naval Observatory)	11 8	−40.5	255.2	+10.5	3		
		−10.0	285.7	+10.5		9	
		+31.0	326.7	−13.0		31	43
May 23 (Naval Observatory)	11 19	−30.0	252.3	+11.5		31	
		+3.0	285.3	+10.5		46	
		+43.0	325.3	−13.0		247	324
May 24 (Naval Observatory)	11 17	−15.0	254.1	+10.5		31	
		+18.0	287.1	+11.0		62	
		+57.0	326.1	−13.0		154	247
May 25 (Naval Observatory)	11 11	−2.5	253.4	+10.5		46	
		+30.0	285.9	+11.0		15	
		+43.0	298.9	−10.0	6		
		+70.0	325.9	−14.0		108	175
May 26 (Naval Observatory)	10 59	+8.5	251.3	+18.0	3		
		+11.5	254.3	+10.5		62	
		+37.5	280.3	+6.0		31	96
May 27 (Naval Observatory)	11 6	+26.0	255.5	+12.5		77	
		+52.0	281.5	+8.0		62	
		+80.0	309.5	+6.0	3		142
May 28 (Naval Observatory)	11 5	+45.0	261.3	+12.0	31		
		+68.0	284.3	+8.0	46		77
May 29 (Naval Observatory)	11 20	+55.0	257.9	+12.5		93	
		+80.0	282.9	+8.0	3		96
May 30 (Naval Observatory)	11 54	−80.0	109.4	+2.5		108	
		+67.0	256.4	+18.0	31		139
May 31 (Naval Observatory)	10 51	−70.0	106.7	+5.0		93	93
Mean daily area for May							184

AEROLOGICAL OBSERVATIONS

[The Aerological Division, W. R. GREGG in Charge]

By L. T. SAMUELS

Free-air temperatures for May were below normal in the lower levels and above normal in the upper levels except at Due West, where the departures decreased appreciably with altitude but remained negative at all levels. (Table 1.)

The relative humidity averaged above normal in the lower levels and mostly below normal in the upper levels.

Vapor pressure departures were in agreement with those for temperature, except that the former remained negative at all levels at Broken Arrow.

The data for Groesbeck have been omitted from Table 1, as kite observations were discontinued at that station on May 16.

Free-air resultant winds for the month at the 1,000-meter level were mostly westerly except on the Pacific coast, where they were very light and variable, and in the extreme southern part of the country, where they were mostly southerly and easterly. (Table 3.)

At 4,000 meters the resultant directions were westerly at practically all stations except in the extreme northern part of the country, where a pronounced northerly component prevailed. The highest resultant velocities at this level occurred over the upper Lakes and New England regions.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1931*

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
TEMPERATURE (°C.)								
Surface	16.6	−3.1	18.5	−1.8	11.4	−1.7	14.9	−1.2
500	15.0	−2.8	16.9	−0.9	10.9	−1.8	12.5	−0.9
1,000	12.9	−2.7	14.5	−0.4	8.7	−0.8	10.0	−0.2
1,500	11.0	−2.4	11.2	−0.6	6.7	+0.1	7.4	0.0
2,000	8.4	−2.4	8.1	−0.8	5.1	+1.5	4.8	−0.2
2,500	5.4	−2.6	5.2	−0.9	2.6	+1.9	2.6	0.0
3,000	2.9	−2.0	2.4	−0.7	−0.2	+1.9	0.3	+0.5
4,000	−1.0	+0.3			−5.6	+2.4	−4.1	+2.2
5,000	−5.2	+1.4			−11.6	+2.5	−9.3	+2.8
RELATIVE HUMIDITY (%)								
Surface	71	+1	69	+4	62	+2	67	+3
500	70	+1	65	0	62	+2	67	+3
1,000	66	−1	59	−5	59	0	65	+2
1,500	58	−4	59	−5	57	−3	60	−1
2,000	56	−3	57	−5	55	−5	54	−3
2,500	55	−1	55	−4	55	−4	50	−1
3,000	53	−1	47	−8	56	−1	53	+6
4,000	37	−18			48	−5	47	+1
5,000	21	−32			50	−1	44	−2

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during May, 1931*—Continued

VAPOR PRESSURE (*mb.*)

Altitude (meters) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	13.70	−2.73	14.98	−0.46	8.41	−0.67	11.54	−0.34
500	12.06	−2.32	12.90	−0.53	8.14	−0.69	9.89	−0.22
1,000	9.84	−1.99	10.21	−0.91	6.47	−0.58	8.01	−0.20
1,500	7.48	−1.84	8.37	−0.79	5.58	−0.31	5.97	−0.61
2,000	5.93	−1.48	6.73	−0.57	4.82	+0.05	4.38	−0.73
2,500	4.86	−0.91	5.17	−0.56	4.12	+0.37	3.42	−0.34
3,000	4.00	−0.58	3.74	−0.67	3.49	+0.58	3.25	+0.55
4,000	2.50	−0.57	------	------	1.78	+0.13	2.37	+0.85
5,000	1.43	−0.64	------	------	1.35	+0.42	1.69	+0.91

TABLE 2.—*Free-air data obtained by airplanes at naval air stations during May, 1931*

Altitude (meters) m. s. l.	Temperature (°C.)					Relative humidity (%)				
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Seattle, Wash.	Washington, D. C.
Surface	18.7	22.0	19.4	18.8	16.4	70	74	72	60	66
500	15.9	19.2	15.8	14.1	15.2	62	73	83	66	59
1,000	13.8	16.7	15.7	10.1	13.8	58	63	67	64	54
2,000	8.7	10.7	13.4	3.2	9.4	45	53	37	61	47
3,000	2.0	4.8	6.2	−1.8	3.7	45	49	27	51	41
4,000	------	------	------	------	−0.7	------	------	------	------	11

TABLE 3.—*Observations by means of kites, captive and limited-height sounding balloons during May, 1931*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,853	2,727	3,268	2,498	3,366
Maximum altitude (meters), m. s. l., reached	[1] 5,906	3,570	[1] 5,600	3,840	[1] 5,737
Number of flights made	33	31	31	[2] 9	30
Number of days on which flights were made	31	30	30	[2] 9	29

[1] Limited-height sounding balloon observation.
[2] Covers period from May 1 to 16, inclusive, only.

In addition to the above, there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during May, 1931*

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,528 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (198 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	N	0.6	S 51 E	1.0	S 44 W	2.9	N 70 W	3.3	S 18 W	0.3	S 10 W	2.0	S 21 E	0.8	N 84 W	0.5	N 37 W	2.4	S 85 W	1.1	N 77 W	0.6	N 57 E	1.7
500	------	----	S 23 E	6.0	S 25 W	5.7	------	----	S 74 W	3.0	S 45 W	4.7	S 22 W	3.3	W	3.4	N 45 W	2.5	------	----	S 69 W	1.2	N 79 E	3.2
1,000	------	----	S 14 E	5.5	S 76 W	5.5	------	----	N 85 W	5.4	S 80 W	5.2	S 59 W	4.2	S 76 W	3.7	N 84 W	2.5	S 76 W	3.2	S 48 W	1.8	S 86 E	2.4
1,500	------	----	S 10 E	4.4	S 87 W	7.1	------	----	S 88 W	6.8	S 81 W	5.3	S 71 W	4.7	S 87 W	3.4	N 59 W	3.4	N 89 W	3.4	S 58 W	1.5	S 65 E	0.7
2,000	S 74 W	1.1	S 6 W	3.2	S 86 W	7.9	N 73 W	5.6	S 85 W	7.4	S 83 W	6.0	N 83 W	4.2	S 87 W	4.1	N 38 W	5.4	N 72 W	4.5	S 62 W	2.2	S 22 W	1.3
2,500	N 77 W	4.2	S 32 W	2.3	N 89 W	8.9	N 63 W	8.0	S 82 W	7.5	S 83 W	6.5	N 84 W	4.9	W	4.8	N 35 W	5.8	N 70 W	4.2	S 63 W	3.0	S 43 W	1.9
3,000	N 67 W	6.3	N 69 W	2.4	N 72 W	12.1	N 55 W	9.0	N 89 W	5.5	S 66 W	6.3	N 70 W	5.1	N 76 W	3.9	N 37 W	5.3	N 67 W	4.0	S 84 W	3.6	S 76 W	2.5
4,000	N 76 W	7.3	N 65 W	7.0	N 78 W	8.9	N 49 W	10.0	------	----	N 81 W	4.3	N 75 W	4.8	N 49 W	4.2	N 26 W	6.2	N 69 W	6.1	N 85 W	5.8	N 80 W	3.9
5,000	S 79 W	6.9	N 59 W	10.0	------	----	N 71 W	8.6	------	----	------	----	N 44 W	3.6	N 66 W	4.3	N 38 W	6.8	N 49 W	6.9	S 89 W	6.2	N 71 W	6.3

Altitude (meters) m. s. l.	Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Oakland, Calif. (8 meters)		Oklahoma, City, Okla. (392 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Surface	N 66 E	0.8	N 79 W	0.3	S 51 W	0.9	N 29 E	0.5	N 8 W	1.6	S 37 W	1.0	N 14 E	0.8	N 66 E	0.9	S 28 E	2.7	N 27 E	0.5	S 32 E	0.5	S 54 W	0.9
500	S 75 E	1.0	N 66 W	0.6	S 85 W	3.5	S 70 W	0.5	N 24 E	1.4	S 40 W	2.5	N 6 W	0.8	N 83 E	0.8	------	----	N 87 E	0.6	N 12 W	0.9	N 84 W	3.7
1,000	N 83 W	1.7	N 58 W	0.8	N 89 W	5.3	S 50 W	1.8	N 16 E	4.3	S 79 W	5.4	N 86 W	2.9	N 28 W	0.4	------	----	N 79 W	1.8	S 50 E	0.4	N 59 W	4.9
1,500	S 59 W	2.7	N 61 E	0.7	N 78 W	6.2	S 62 W	3.3	N 29 E	3.5	N 84 W	4.5	N 79 W	4.5	N 67 W	1.3	S 15 E	3.5	N 65 W	3.7	S 53 W	1.0	N 79 W	6.0
2,000	N 60 W	1.4	N 15 E	1.2	N 77 W	6.2	S 79 W	3.1	N 22 E	4.4	N 85 W	6.0	N 79 W	5.6	N 73 W	1.5	S 24 W	2.5	N 79 W	5.3	N 79 W	3.2	N 80 W	6.9
2,500	S 81 W	2.8	N 41 W	1.8	N 71 W	5.5	N 87 W	3.8	N 7 E	3.6	N 77 W	6.2	N 66 W	5.5	S 76 W	2.1	S 83 W	3.5	N 79 W	7.0	N 82 W	5.2	N 76 W	5.9
3,000	------	----	N 46 W	3.6	N 70 W	3.8	N 72 W	4.8	N 21 W	7.5	N 71 W	4.8	N 64 W	7.2	S 72 W	2.1	N 87 W	4.4	N 72 W	8.8	N 63 W	4.8	N 80 W	4.9
4,000	------	----	N 56 W	6.2	------	----	S 89 W	6.6	------	----	N 70 W	5.7	N 79 W	6.2	S 57 W	2.8	N 72 W	6.9	N 25 W	10.8	------	----	N 79 W	4.9
5,000	------	----	------	----	------	----	N 57 W	4.8	------	----	------	----	N 52 W	7.7	N 70 W	6.2	------	----	N 27 W	12.8	------	----	------	----

WEATHER IN THE UNITED STATES

[Climatological Division, Oliver L. Fassig, in Charge]

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

For May as a whole temperature averaged from 2° to 6° below normal from western Ohio, middle Mississippi and lower Missouri valleys southward, while generally in the northern Great Plains and west of the Rocky Mountains the month was decidedly warmer than normal. Abnormally low temperatures prevailed about the 20th of the month with freezing weather as far south as Iowa and parts of Kansas. Thereafter warmer weather prevailed, with high temperatures the latter part of the month in the interior and Eastern States. The precipitation during the month was unevenly distributed, but considerable areas, especially in the East, had more than the normal amounts. Many portions of the Atlantic States from Florida to New England received from 25 to 50 per cent more than the average for the month, and other areas in the interior comprising northern Illinois and Missouri and portions of the Southwest had more than normal. Large deficiencies occurred in the Central Gulf States and the Northwest between the Lake region and the Rocky Mountains, as well as in the Pacific Northwest. But the smallest percentages of normal occurred in the eastern portions of Washington and Oregon and much of Arizona where less than 25 per cent of the normal was recorded.

TEMPERATURE

West of the Continental Divide warm weather prevailed nearly all the month, and in the extreme Northwest the first half of the middle decade was especially notable for high temperatures.

From the Rocky Mountains eastward cool and warm periods alternated. A well-marked cool period affected nearly all of the middle and eastern sections about the 6th to 13th, but somewhat higher temperatures succeeded, especially in the upper Mississippi Valley, Lake region and Northeastern States.

A notable cool spell set in over the northern Plains about the 18th and advanced southward and eastward, reaching the Atlantic coast about the 22d; the duration of the cool weather was usually about four days, and the remainder of the month was marked by practically normal temperatures in most middle and eastern sections, save that high marks were reached from the 27th to the 31st in much of the Lake region and especially in the Middle and North Atlantic States.

In nearly all States east of the Rocky Mountains the month averaged cooler than normal, especially in the middle and southern Plains, the west Gulf region and the central valleys, where it averaged usually 3° to 5° cooler. In some Southeastern and South-Central States it was the third successive month to average considerably cooler than normal, and save February no month since September, 1930, has been warmer than normal in these sections. On the other hand, in Michigan, Wisconsin, Iowa, Minnesota, and South Dakota, May was the first month since October, 1930, to average cooler than normal.

Pennsylvania, New Jersey, New York, and New England averaged slightly warmer than normal, likewise North Dakota. In Montana and the Plateau and Pacific States the month was warmer than normal, usually to a marked extent. California averaged almost 6° hotter than normal, and in that State and Nevada every month so far this year has averaged at least 1° above. The warmth since early March in southern California has been particularly notable. Los Angeles recorded no spring month previous to 1931 warmer than May, 1885, when the mean temperature was 65.6°. This year March and April each averaged 66°, 8.5° and 6.6° above normal, respectively, amd May 67.5°, 5.3° above normal.

The highest temperatures during May in the States of the eastern half were usually from 93° to 98°, and occurred chiefly about the middle of the month or during the last five days. Marks above 100° were noted in nearly every State of the western half, the highest being 114° in California. These occurred usually about the 14th, on the 25th, or during the final two days.

In some Gulf States the lowest temperatures were as high as 40°, but mainly they were from 10° to 30°, save below 10° in some Rocky Mountain States. The dates of occurrence were scattered through the month, many Northeastern States noting them on the 1st, and other Eastern and Middle States, as a rule, either about the 8th or 12th, or else between the 20th and 24th.

PRECIPITATION

The rainfall for the western half of the cotton region, which was poorly distributed and mainly much below normal, occurred chiefly during the opening week, or about the 20th; while in the eastern cotton region the distribution was better, yet most districts had by far the greater part of the month's supply during the first fortnight. The upper Ohio Valley had liberal rains about the middle of the month. In the Atlantic States from North Carolina northeastward the most important rains came near the close of the first decade or during the final decade.

The precipitation of the central valleys and the Lake region was comparatively well distributed in point of time, but much occurred about the 19th. The central Rocky Mountain region received its most important falls during the early days or else about the 28th.

The monthly totals were less than normal over considerably the larger part of the country. In the middle and upper Missouri Valley and thence westward to the north Pacific coast there was a marked deficiency, particularly in Idaho, Oregon, the eastern half of Washington and northern Montana, which usually received but one-quarter to two-fifths of the normal. The western half of the country otherwise had usually less than normal, save some parts of central and southern California, a strip extending from northeastern Colorado to the Texas Panhandle, and most of the lower Rio Grande Valley.

In the eastern half there was usually less than normal in the Gulf States, Arkansas, Tennessee, and the southern Appalachian region, in most of the lower Ohio and upper Mississippi Valleys and in much of the Lake region, especially near Lakes Erie and Huron. From northeastern Florida to central New England there was nearly everywhere an excess and a rather large excess occurred in the middle Appalachian region and the upper Ohio Valley. Much of Illinois and the lower Missouri Valley had a slight excess.

The largest amount reported from one station was 12.97 inches at Center Hall, Pa.

This month was the first since October, 1929, to bring more than normal precipitation at Washington, D. C. However, at Charleston, S. C. it was the eleventh consecutive month with less than normal.

In the Missouri Valley and to westward numerous districts have fallen far below their normal precipitation

for many months. At Helena, Mont., every month of the last six has failed to bring as much as half its normal precipitation; while at Sioux City, Iowa, Pocatello, Idaho, and Eureka, Calif., no single month yet this year has brought as much as 70 per cent.

SNOWFALL

There was no important snowfall over the Plains or to eastward, except in a very few districts. About the 20th nd 21st small amounts fell in eastern North Dakota and to eastward to the vicinity of Lake Superior, while three days later there was a moderate snowfall over much of south-central New York and northeastern Pennsylvania. A considerable portion of eastern Colorado and some parts of adjoining States had rather large amounts for the latter half of May about the 21st.

In the Pacific and Plateau States and practically all of Montana the month's snowfall was unimportant. On the other hand, some portions of the Rocky Mountains had much new snow, two Colorado stations each measuring more than 50 inches during the month.

SUNSHINE AND RELATIVE HUMIDITY

The Southwest generally, much of the Great Plains, the southern Rocky Mountains and most of the Plateau and portions of the lower Lake region received more than the normal amount of sunshine, while in the central and upper Mississippi Valley much cloudy weather prevailed. Elsewhere about the usual amount of sunshine for May was received. The relative humidity was below the normal generally from the upper Mississippi Valley westward to the Pacific and also throughout the central portions of the Rocky Mountain and Plateau regions, while in the Atlantic States, the Ohio and central Mississippi Valleys and the far Southwest it was generally above the normal, but the plus departures were in no case large.

SEVERE LOCAL STORMS, MAY, 1931

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Yakima, Wash	1	2:30 p. m.				Whirlwind	Several small buildings wrecked	Official, U. S. Weather Bureau.
Riogrande, Tex	1	4:30 p. m.	4 mi.		$2,500	Hail	Roofs damaged; glass broken	Do.
Bishop, Tex	2	5 p. m.				Hail and wind	Crops and buildings damaged; path 35 miles long.	Do.
Grand Junction, Colo. (near)	3	5–6 p. m.	1–3 mi.			Hail	Considerable damage to pears	Do.
Stanton, Kearney, Finney, Haskell and Gray Counties, Kans.	4	3–5 p. m.	1–6 mi.		1,500,000	Hail and wind	Heavy loss of crops, chiefly wheat; buildings damaged; path 100 miles long.	Do.
Cimarron, Kans. (near)	4	4 p. m.	6		300	Small tornado	Several small buildings damaged; path 3 miles long.	Do.
Blair and Humphrey, Okla., and vicinity.	4	4–5 p. m.	5 mi.		6,700	Hail	Chief damage to crops; path 15 miles long	Do.
Ness County, Kans	4	4:45 p. m.	900		25,000	do	Damage chiefly to wheat; path 7 miles long	Do.
Davenport, Fla	4	6 p. m.	2,640			do	Young citrus fruits considerably damaged	Do.
Electra, Tex	4	6:30 p. m.				Wind, hail, and rain.	Roofs, chimneys, and merchandise damaged	Do.
Camden, Miss. (near)	4	A. m.			15,000	Tornado and hail	Buildings, fencing, and crops damaged; many large trees uprooted.	Do.
Jefferson and Page Counties, Iowa.	5	9:30–10:30 a. m.			10,000	Wind	Overhead wires and trees considerably damaged.	Do.
Camilla, Ga	5				7,000	Wind, rain, and hail.	Several roofs damaged; trees blown down	Do.
Fredericksburg, Kerrville, and Comfort, Tex.	6	2:30 p. m.	4 mi.		25,000	Wind and hail	Cars and buildings damaged; considerable injury to crops.	Do.
Canning to Onida, S. Dak	6	7–8 p. m.	8 mi.		25,000	Hail and wind	Several small buildings wrecked and other property damaged; 3 children injured.	Do.
Madison, Wis. (11 miles east)	6		50		75	Small tornado	Farm property damaged	Do.
Pittsburgh, Pa	7					Severe thunderstorm.	Streets flooded; electric wires damaged	Do.
Rock Hill, S. C. (near)	7				1,000	Hail	Crops damaged	Do.
Dinwiddie and Prince Georges Counties, Va.	9	6–7 p. m.	¼–4 mi.			Hail and wind	Barns wrecked; fruits ruined in small area	Do.
Parkersburg, W. Va	9				100,000	Severe thunderstorm.	A fire caused by lightning partially destroyed a mill.	Do.
Windsor, N. C., and vicinity	9					Hail	Tobacco beds and other crops damaged; roofs and windows pierced; poultry killed.	Do.
Bascom, Fla	10	3 a. m.	1,760			do	Cotton and corn probably total loss	Do.
Albany, N. Y., and vicinity	10	5:15 p. m.	5 mi.		150,000	do	Poultry killed, auto tops and windows broken; roofs and small buildings damaged; fruit trees stripped; telephone company suffered loss.	Do.
Virginia (southeast counties)	10	4 p. m.	5 mi.		10,000	do	Character of damage not reported	Do.
Burlington County, N. J	10	7:30 p. m.			300,000	do	Severe crop damage; fruit trees stripped; car tops dented.	Do.
Clinton, N. J., and vicinity	10	7:30 p. m.			25,000	do	Crops injured; some property damaged	Do.
Phelps and Junius, N. Y	10		1,760			do	Fruit trees hurt; windows broken	Do.
Montrose, Pa	10				5,000	Thunderstorm	Barn and contents destroyed	Do.
Thomas County, Ga. (northwestern).	10		1,760		1,500	Wind, rain, and hail.	Buildings and crops on one plantation damaged.	Do.
Cooperstown, N. Y	11					Small tornado	A few roofs, trees, and garages damaged	Do.
Greenbrier County, W. Va. (Falling Springs district).	11					Hail	Roofs and auto tops riddled; windows broken; fruit trees stripped; gardens ruined; poultry killed.	Do.
King William and Gloucester Counties, Va.	13	2–4 p. m.	5–10 mi.		6,000	do	Melon and truck crops seriously damaged	Do.
Newman Grove, Nebr	17	4–5 p. m.	3 mi.		3,000	Wind and hail	Farm buildings damaged; crops injured; path 10 miles long.	Do.
Dickinson County, Iowa	17	5 p. m.			8,000	Tornado and hail	Character of damage not reported	Do.
Osceola County, Iowa	17	5:30 p. m.			5,500	Tornado	Buildings damaged; livestock injured or killed; path 3 miles long.	Do.
Marietta, S. C	17				1,000	Hail	Crops damaged	Do.
Tennessee (eastern)	17–18					do	Fruit and other young crops damaged	Do.
Russell County, Va	18	2 p. m.	2 mi.			do	Considerable damage, character not reported	Do.
Belmont and adjacent counties, Ohio.	18–19				100,000	do	Crops, buildings, and other property severely damaged.	Do.
Sallis, Miss. (4 miles west)	19	A. m.				Violent wind	A barn and residence demolished; 1 person injured; storm covered about an acre.	Do.

[1] "Mi" signifies miles instead of yards.

Severe local storms, May, 1931—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cumberland County, Pa. (western).	19	P. m.			10,000	Severe thunderstorm.	Barn burned; many small buildings damaged.	Official, U. S. Weather Bureau.
Comanche, Tex.	19		1,760		2,500	Hail	Crops and buildings damaged.	Do.
Terra Haute, Ind. (near)	19				1,500	Wind	Damage to farm buildings.	Do.
Mobile, Ala.	20					Thundersquall	Trees blown down; electric service interrupted.	Do.
Clay County, Nebr. (southwestern).	21	3:30 a. m.	3 mi.		5,000	Wind	Character of damage not reported.	Do.
Roxana to Skellytown, Tex.	21	2:30 p. m.			40,000	Tornado	Crops and other property severely damaged.	Do.
Albany, Tex.	21	6:30 p. m.			15,000	Hail	Buildings damaged; minor crop injury.	Do.
Cotton County, Okla.	21	7 p. m.	880–1,760		52,000	do	Chief damage to crops; path 20 miles long.	Do.
Latimer County, Okla. (northern).	21	11 p. m.	2,640		3,000	do	Some damage to crops and other property.	Do.
Virginia (southwestern)	22	2–5 p. m.	2–18 mi.		51,000	Hail and wind	Heavy crop loss.	Do.
Victor, Dublin, and Carlton, Tex.	22	8 p. m.	9 mi.		40,000	Hail	Crops destroyed or injured; houses damaged; poultry and lambs killed.	Do.
Anna, Ill. (near)	22					do	Injury to property slight to severe.	Do.
Caldwell and Burke Counties, N. C.	22				50,000	do	Crops severely damaged; roofs pierced.	Do.
Stanley County, N. C.	22					do	Much small grain destroyed; replanting of cotton necessary; gardens total loss.	Do.
Atchison County, Kans.	24	11–12 p. m.	1,300		7,000	Hail and wind	Injury chiefly to apples, pears, and gardens; path 3 miles long.	Do.
Waukesha and Racine Counties, Wis.	24		10 mi.		5,000	Hail	Roofs damaged; trees blown down; fruit injured.	Do.
Snyder, Tex.	25	4 p. m.			3,000	do	Crops damaged.	Do.
Lancaster, Ohio	25	4:30 p. m.				Probably tornado.	Character of damage not reported.	Do.
Crozet, Va., and vicinity	26	2:30–6:30 p. m.	1,760		40,000	Hail	Trees, fruits, and gardens severely hurt; path 7 miles long.	Do.
Moorhead (10 miles southeast) to Gary, Minn.	27	4:15 p. m.		2	200,000	Tornado	Passenger train lifted from rails; several buildings wrecked; farm machinery damaged; livestock injured or killed; some fields require replanting; 57 persons injured; path 40 miles long.	Do.
Jewell, Rooks, and Osborne Counties, Kans.	27	8–11 p. m.				Hail	Damage chiefly to wheat.	Do.
Thomas and Grady Counties, Ga.	27				2,000	do	Crops injured over path several miles long.	Do.
Harlan County, Nebr.	28	2 a. m.	1–2 mi.		75,000	Wind	20 barns damaged; many windmills wrecked; path 30 miles long.	Do.
Scott County, Iowa	28	2:30 p. m.	490		2,500	Tornado and wind	Character of damage not reported; path 2 miles long.	Do.
Des Moines County, Iowa	28	3 p. m.				Tornado and hail.	No details reported; path 4 miles long.	Do.
Oneida, Ill.	28	4:30 p. m.			5,000	Wind	Buildings damaged; trees uprooted.	Do.
Galva, Ill. (south)	28					Severe thunderstorm and wind.	Farm buildings blown down or unroofed; trees uprooted.	Do.
Dawson, N. Mex.	29	2:30 – 3:30 p. m.	2 mi.		1,000	Hail	Gardens and flowers ruined; too early for crops.	Do.
Field, N. Mex. (near)	29	2–6 p. m.	6 mi.		21,000	do	Severe damage, character not reported.	Do.
Charlottesville, Va. (near)	30	3:05 p. m.	1,500		9,000	Tornado	Chief damage to airplane hangar and 3 planes.	Do.
Grove City, Pa.	30	6 p. m.	100		5,000	Thundersquall	College buildings damaged.	Do.
Bradford County, Pa.	30	P. m.				Thunderstorm and wind.	Damage chiefly to crops.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES, in charge River and Flood Division

Overflows in the southern part of the Atlantic slope drainage caused miscellaneous damage to the extent of about $8,000. Timely forecasts were issued and were generally heeded, which reduced the losses to a minimum.

Minor local floods in the Kansas, Canadian, Guadalupe, Pecos, and Colorado Basins caused no damage of consequence.

Stages are very low throughout most of the Mississippi River system, and many stations report the lowest of record for May. Streams are also low in the Pacific slope drainage.

Final reports of the overflows in the Columbia River Basin in March and April indicate the flood damage was about $10,000 along streams where a flood-warning service is maintained. Along streams where there is no warning service the damage amounted to about $50,000. Savings effected through the warnings were estimated at $25,000. At Walla Walla, Wash., there was a severe flood in Mill Creek, destroying or damaging property to the extent of $500,000.

Table of flood stages in May, 1931

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Tar: Rocky Mount, N. C.	9	10	10	9.0	10
Neuse: Smithfield, N. C.	14	24	26	14.8	25
Cape Fear: Elizabethtown, N. C.	22	23	26	26.6	24
Peedee:					
Cheraw, S. C.	27	23	24	28.6	23
Mars Bluff Bridge, S. C.	17	25	29	18.4	27
Saluda: Pelzer, S. C.	7	21	22	7.4	22
Santee: Rimini, S. C.	12	9	10	12.0	10
		24	27	12.7	27
Oconee: Milledgeville, Ga.	22	5	5	23.5	5
Altamaha: Charlotte, Ga.	15	13	15	15.4	14
MISSISSIPPI SYSTEM					
Missouri Basin					
Solomon: Beliot, Kans.	18	6	6	20.4	6
Republican: Concordia, Kans.	8	5	5	8.3	5
Arkansas Basin					
Canadian: Logan, N. Mex.	4	2	2	5.6	2
		4	4	5.0	4
		30	30	6.0	30
WEST GULF OF MEXICO DRAINAGE					
Guadalupe: Victoria, Tex.	16	5	5	16.2	5
Pecos: Pecos, Tex.	11	1	2	11.6	1
		5	5	11.0	5
GULF OF CALIFORNIA DRAINAGE					
Colorado: Parker, Ariz.	7	24	31	7.9	25–26

THE WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[Marine Division, W. F. McDONALD, in charge]

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather over the eastern section of the ocean during May was somewhat quieter than usual, gales occurring on from one to four days in different 5° squares in that region. Over the western section disturbances of any importance were unusually rare, as gales were not reported on more than one day in any 5° square west of the forty-fifth meridian.

The comparatively small departures at most of the coast and island stations as shown in Table 1, indicate that the pressure distribution over the greater part of the ocean was not far from normal.

The most unusual feature of the month was the remarkably severe disturbance near the Equator on the 2d, as reported by the observer on board the Norwegian M. S. *Ima*, and shown in table of gales and storms.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian) North Atlantic Ocean, May, 1931*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Belle Isle, Newfoundland	29.87	[1] −0.07	30.40	24th	29.20	4th.
Halifax, Nova Scotia	29.98	[2] +0.01	30.28	7th	29.54	15th.[3]
Nantucket	29.96	[2] −0.03	30.20	1st [3]	29.56	14th.
Hatteras	29.99	[2] −0.04	30.24	28th	29.64	13th.
Key West	29.96	[2] −0.02	30.12	15th [3]	29.82	31st.
New Orleans	30.00	[2] 0.00	30.20	15th	29.82	9th.
Turks Island	30.00	[1] 0.00	30.12	16th	29.92	30th.[3]
Bermuda	30.05	[2] −0.06	30.26	19th [3]	29.86	14th.
Horta, Azores	30.16	[1] +0.02	30.32	2d [3]	29.90	8th.
Lerwick, Shetland Islands	29.82	[1] +0.02	30.19	8th	29.36	15th.
Valencia, Ireland	29.75	[1] −0.20	30.20	8th	29.34	29th.
London	29.87	[1] −0.05	30.25	9th	29.46	17th.

[1] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[2] From normals based on 8 a. m. observations.
[3] And on other date or dates.

As in April, fog was unusually prevalent over the western section of the ocean, and the number of days on which it was reported in different localities is as follows. Over the Grand Banks, from 12 to 14 days; along the American Coast between the thirty-fifth and fortieth parallels, on 12 days; along the American coast north of the fortieth parallel, from 12 to 16 days; over the steamer lanes between the tenth and fortieth meridians, from 1 to 2 days; off the coast of Europe, from 1 to 5 days; in the Gulf of Mexico, on 3 days.

During the first four days of the month moderate conditions prevailed generally, except for the depression that was off the south coast of Newfoundland on the 4th, and afterwards developed into a disturbance that reached its greatest intensity on the 7th and 8th, and is shown on Charts VIII to XI covering the period from the 5th to 8th.

A second disturbance that was over the mid-eastern section of the steamer lanes on the 11th moved slowly eastward and on the 13th was centered about 300 miles west of Valencia, Ireland.

From the 17th to the 23d moderate to strong gales were reported by a number of vessels over a considerable area in mid-ocean, while during this period moderate weather prevailed west of the fortieth meridian.

From the 24th until the end of the month there ensued a period of comparatively slight wind movement, and few reports were received from vessels encountering a wind force of 7 or over, although on the 29th the land stations at Cape Race, Newfoundland, and Lerwick, Shetland Islands, both reported winds of force 8 with rain.

Notes.—British steamship *Coronado*, Capt. A. W. Legge; observer, G. Binks, third officer. From Avonmouth to Jamaica:

Sunday, May 10, 1931, at 2.30 p. m. A. T. S., in latitude 21° 34′ N., longitude 71° 05′ W., observed a waterspout bearing WSW., approximate distance 10 miles. Barometer 29.91 inches. Clouds Cu. Nb. 2. The spout was vertical and very well defined, very dark at the top, base becoming lighter in the middle. The sea at the base was disturbed and rose up conically to the spout that lasted about 5 minutes, finally being dispersed in a heavy rain squall. Half an hour later while lying off Grand Turk another waterspout was observed appearing to lie over Caicos Island. This spout was identical in size and shape to the former and lasted about 7 minutes, finally dispersing in heavy rain.

Lekhaven, Dutch steamship, Capt. T. Yaski; observer, Y. M. Groenweg, second officer. From Buenos Aires to Amsterdam:

At 5 a. m. May 26, 1931, in latitude 34° 40′ N., longitude 15° 32′ W., saw a waterspout, distance about 6 miles, height about 10 degrees. Wind SW., 2. Barometer 30.03 inches. Temperature, air 65°; water 65°. Blue sky, smooth sea, slight confused swell.

OCEAN GALES AND STORMS, MAY, 1931

Vessel	Voyage From—	Voyage To—	Position at time of lowest barometer Latitude	Position at time of lowest barometer Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Ima, Nor. M. S.	Singapore	Lands End	3 10 N	12 08 W	May 2	1 p. 2	May 2		NE	NE, 8	NE	NE, 9	Steady.
Greystoke Castle, Br. M. S.	Port Said	New York	39 23 N	65 00 W	May 3	9 a. 3	May 3	29.74	S	S, 7	W	—, 8	S-SSW.
Boston City, Br. S. S.	Fowey	Portland, Me.	45 13 N	38 52 W	May 4	2 p. 6	May 8	29.54	S	WNW	NW	NW, 9	W-WNW.
General von Steuben Ger. S. S.	Southampton	New York	43 14 N	43 31 W	May 6	9 a. 6	May 7	29.57	W	WSW, 7	NW	WNW, 9	
East Indian, Am. S. S.	Antwerp	do	45 30 N	42 15 W	May 7	2 p. 7	May 8	29.16	WNW	W, 9	NNW	WNW, 10	W-NNW.
Sarcoxie, Am. S. S.	Harve	do	46 41 N	30 25 W	do	7 a. 7	do	29.28	S	W, 10	W	W, 10	S-W.
Tulsa, Am. S. S.	Manchester	Savannah	50 08 N	19 50 W	May 10	1 p. 10	May 10	29.48	SSW	SSW, 9	W	SSW, 9	SSW-W.
Bellhaven, Am. S. S.	Boston	Manchester	48 31 N	38 50 W	do	Mdt. 11	May 13	29.01	SW	SW, 7	WNW	W, 11	SW-W.
Dresden, Ger. S. S.	Bremerhaven	New York	48 54 N	26 06 W	May 11	8 p. 11	May 12	29.37	SSW	SW, 10	WNW	W, 10	
Statendam, Du. S. S.	Rotterdam	do	47 50 N	25 36 W	do	10 a. 12	May 13	29.67	SSW	WSW, 8	WNW	WSW, 9	WSW-W.
Europa, Gr. S. S.	Cherbourg	do	49 04 N	19 24 W	May 12	2 a. 13	do	29.54	SSW	WSW, 7	W	W, 10	WSW-W.
Bannock, Am. S. S.	Cork	do	50 43 N	30 42 W	May 17	2 a. 17	May 20	29.37	SW	SW, 6	NW	W, 10	SW-W.
Ambridge, Am. S. S.	Antwerp	do	49 08 N	21 58 W	do	Noon 17	May 18	29.23	WNW	WNW, 8	NW	WNW, 10	WNW-NW.
Meanticut, Am. S. S.	Rotterdam	Galveston	46 17 N	14 41 W	do	do	do	29.34	W	W, 7	NW	WNW, 10	W-WNW.
Ambridge, Am. S. S.	Antwerp	New York	46 49 N	31 23 W	May 19	Noon 19	May 22	29.87	WSW	WSW, 7	W	W, 10	
Jean Jadot, Belg. S. S.	do	do	47 00 N	30 00 W	May 21	4 p. 21	do	29.51	NW	NW, 8	NW	—, 10	
Elmsport, Am. S. S.	Hull	Jacksonville	42 05 N	21 10 W	do	6 p. 21	May 23	29.63	WNW	NW, 10	WNW	NW, 10	WNW-NW.
Gonzenheim, Ger. S. S.	Emden	Baltimore	50 43 N	17 33 W	May 22	4 a. 23	May 24	29.13	ESE	NE, 10	NNW	N, 10	NE-N.
SOUTH ATLANTIC OCEAN													
Lekhaven, Du. S. S.	Buenos Aires	Amsterdam	32 40 S	49 10 W	May 3	Noon 5	May 6	29.67	SW	WNW, 8	WSW	WNW 9	
Portfield, Br. S. S.	Penarth	River Plate	34 30 S	53 00 W	May 19	8 p. 19	May 20	29.37	SW	SW, 8	SW	SW, 9	Steady.
NORTH PACIFIC OCEAN													
Golden Star, Am. S. S.	Hong Kong	San Francisco	43 10 N	159 35 E	Apr. 30	6 p. 30	May 1	29.03	SE	SE, 8	SW	SE, 9	SE-SW.
Chattanooga City, Am. S. S.	Kahuilui	Kobe	30 05 N	154 30 E	May 1	8 a. 2	May 2	29.65	SW	W, 8	N	W, 8	SW-W-WNW
Grays Harbor, Am. S. S.	Hong Kong	San Francisco	27 08 N	123 58 E	May 7	2 p. 8	May 8	29.92	NW	NNW, 8	N	NNW, 8	N-NNW.
Resolute, Ger. S. S.	Hilo	do	37 17 N	123 38 W	do	Mdt. 7	do	30.09	NNE	N, 8	N	N, 9	Steady.
Golden Star, Am. S. S.	Hong Kong	do	[1] 47 00 N	154 00 W	May 8		May 9		SSE		WNW	SW, 11	
Silveryew, Br. M. S.	San Francisco	Yokohama	45 54 N	170 40 E	May 9	4 p. 9	May 10	29.68	SW	SW, —	NNW	W, 10	SW-W.
Pres. Taft, Am. S. S.	Victoria	do	50 14 N	177 04 E	do	1 a., 10	do	29.12	S	WSW 8	NW	WNW, 9	WSW-W-WNW
Fukuyo Maru, Jap. S. S.	Japan	Coos Bay	46 35 N	166 35 E	May 8	10 p. 8	May 12	[3] 29.69	SW	WSW, —	WNW	WNW, 9	
San Diego Maru, Jap. M. S.	Elwood	Kudamatsu	33 25 N	137 25 E	May 11	6 p. 12	May 13	29.72	E	NE, 10	NE	NE, 10	E-NE.
Everett, Am. S. S.	Tacoma	Yokohama	51 37 N	172 00 W	May 12	6 p. 12	do	29.33	NE	NE, 7	NW	NW, 9	N-NW.
Chief Capilano, Br. S. S.	Yokohama	Port Alberni	49 11 N	179 37 W	May 13	2 p. 13	May 14	29.05	E	NNE, 7	NW	NNE, 8	NNE-N-NNW.
Shelton, Am. S. S.	Aomori	San Francisco	48 20 N	156 30 W	May 15	2 a. 15	May 16	[3] 29.27	WNW	WNW, 8	W	N, 9	WNW-W.
Oregon, Am. S. S.	Weihaiwei	do	32 41 N	133 54 E	do	Noon 15	do	29.37	SE	SE, 11	WSW	SE, 11	SE-SSE.
Emidio, Am. S. S.	San Pedro	Vancouver	35 40 N	121 36 W	May 16	6 p. 16	May 19	30.02	NW	NW, 7	N	N, 9	
Silverhazel, Br. M. S.	Honolulu	San Francisco	37 15 N	123 30 W	May 17	8 a. 18	May 18	30.15	NNW	NNW, 8		NNW, 10	Steady.
Everett, Am. S. S.	Tacoma	Yokohama	39 00 N	144 05 E	May 22	6 p. 23	May 24	29.22	SE	S, 8	NNW	SE, 10	SE-S-NW.
Hakubasan Maru, Jap. M. S.	Yokohama	San Francisco	[2] 42 27 N	162 15 W	May 25	— 25	May 26	[3] 29.30	NNE	NNE, —		NNE, 9	NNE-SSE.
SOUTH PACIFIC OCEAN													
Brunswick, Pan. M. S.	San Pedro	Auckland	35 00 S	177 00 E	May 7	4 a. 8	May 8	[3] 29.44	NNE	SE, 10	SSE	SE, 10	ENE-SE.
Crown City, Am. M. S.	Port Lincoln	Shanghai	35 34 S	122 46 E	May 9	Noon 11	May 13	29.25	NE	NW, 10	SW	NW, 11	NE-N-NW.

[1] Position approximate. [2] Barometer uncorrected. [3] From G. M. N. observation.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—Sharp contrasts of atmospheric pressure between different periods of the month occurred over most of the Aleutian region and the Gulf of Alaska during May, 1931. For the first 17 days a fairly strong development of the Aleutian cyclone was in evidence, and for the last 14 days a considerable reversal of the LOW in favor of strong high pressure occurred, with barometer readings as high as 30.60 inches on the 19th and 22d, so that the average for the month showed practically normal pressure over the entire gulf and the Aleutians.

In the region usually occupied by the North Pacific HIGH there were few intruding low-pressure areas in May, and none of a marked stormy nature, the anticyclone remaining generally in a well developed state in west longitudes.

In middle latitudes on the Asiatic side of the ocean pressure was unstable, and numerous LOWS appeared, some of continental and some of oceanic origin. These caused frequently unsettled weather, such as is characteristic of the transition period between the summer and winter monsoons.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, May, 1931*

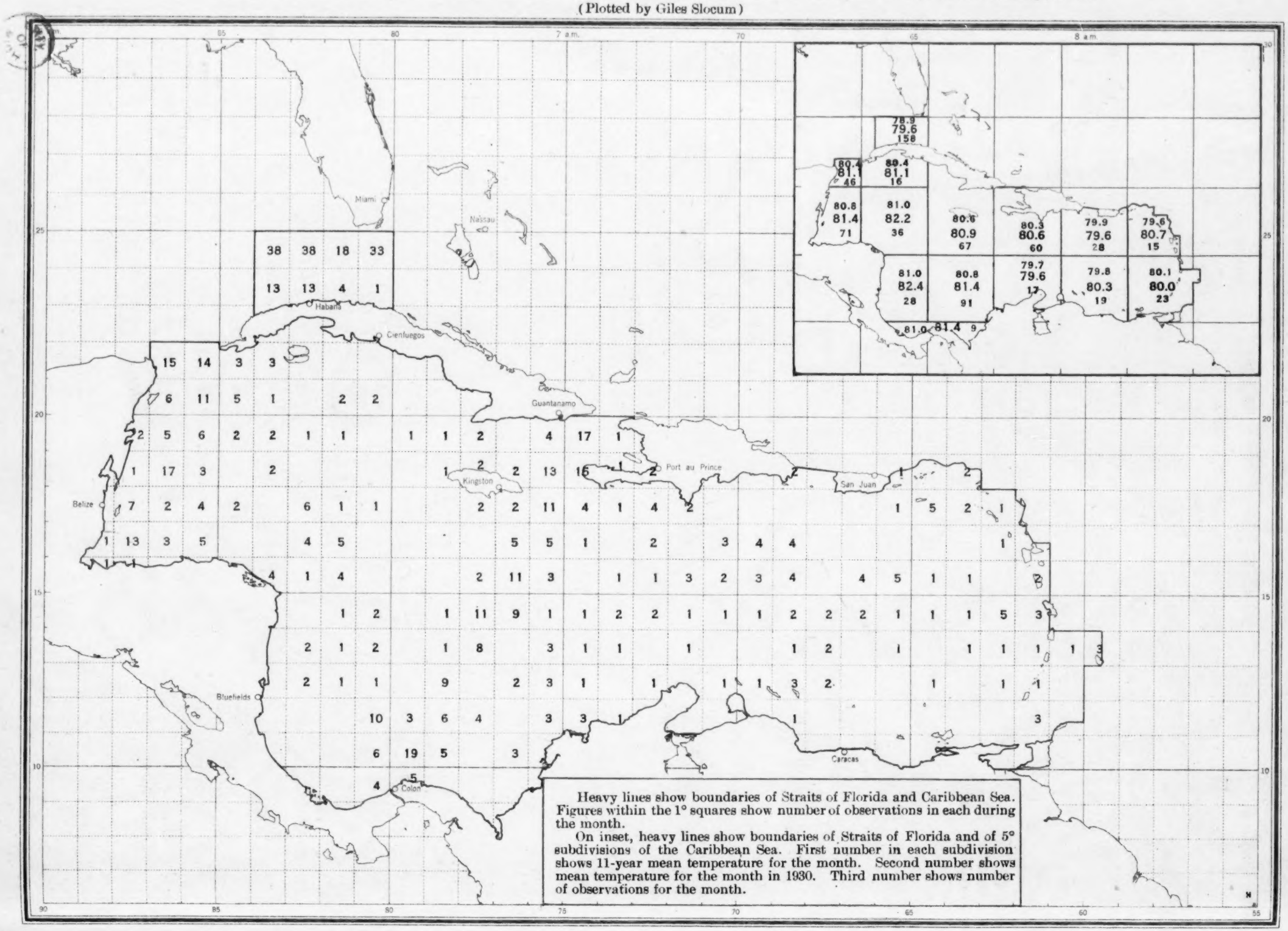
Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.11	+0.02	30.90	1st	29.44	24th.
Dutch Harbor [1]	29.88	+0.04	30.64	22d	29.08	10th.
St. Paul [1] [2]	29.88	+0.04	30.60	22d	29.04	5th.
Kodiak [1]	29.79	−0.05	30.60	19th	29.16	4th. [3]
Midway Island [1]	30.09	+0.04	30.30	19th	29.68	1st.
Honolulu [4]	30.03	−0.02	30.13	15th	29.92	20th.
Juneau [4]	29.97	−0.02	30.60	19th	29.39	23d.
Tatoosh Island [4] [5]	30.09	+0.05	30.59	18th	29.67	21st.
San Francisco [4] [5]	29.94	−0.04	30.18	17th	29.75	21st.
San Diego [4] [5]	29.93	0.00	30.03	23d	29.84	25th.

[1] P. m. observations only.
[2] For 30 days.
[3] And on the 10th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

Cyclones and gales.—With the near approach of summer there was a considerable diminution of storminess over

Distribution of Greenwich Mean Noon Bucket Observations of Sea-Surface Temperatures, May, 1930

(Plotted by Giles Slocum)



Heavy lines show boundaries of Straits of Florida and Caribbean Sea. Figures within the 1° squares show number of observations in each during the month.

On inset, heavy lines show boundaries of Straits of Florida and of 5° subdivisions of the Caribbean Sea. First number in each subdivision shows 11-year mean temperature for the month. Second number shows mean temperature for the month in 1930. Third number shows number of observations for the month.

the upper and middle waters of the North Pacific, and no severe disturbances seem to have occurred in the tropics. The regions over which the principal gales of the month occurred may be grouped as follows: One lying immediately south of Japan; another stretching southwestward from the western Aleutians well toward northern Japan; a third running closely along the American coast between Vancouver Island and about Point Conception, Calif.

The gales in lower Japanese waters were mostly caused by two cyclones which came from the Asiatic mainland near the middle of the month. The earlier passed along the lower coasts of the islands and caused strong to whole gales on the 12th. The second cyclone at time of greatest intensity was central over the Japan Sea on on the 15th, during which day gales with force as high as 11 occurred in the southern quadrants east of Kiushu Island. On the 23d, in connection with another cyclone over the Archipelago, a whole southeast gale was reported near the east coast of Honshu.

For that portion of the upper steamship routes lying southwest of the Aleutians the principal gale period embraced the 9th to 11th, with local maximum wind forces of 9 and 10 on the 9th. On other days scattered gales were encountered by steamships, but none was reported as exceeding force 8.

In the American coastal region northerly to westerly gales occurred on the 7th to 9th, and again on the 17th to 19th. In the earlier period the high velocities were due to the steep pressure gradients on the eastern slope of the Pacific anticyclone impinging upon a LOW, the western side of which bordered on the coast. At this time the strongest gale reported was of force 9, experienced about 100 miles west of San Francisco. In the second period there was a strong concentration of the ocean HIGH off the Washington and Oregon coasts, and in consequence of steep gradients east of the crest anticyclonic gales of force 8 to 10 roughened the weather off Oregon and the upper half of California, with moderate gales (force 7) covering a wider range of sea.

The only severe gale mentioned for the entire ocean area apart from the regions noted was a southwesterly wind of storm force (11) reported on the 8th in approximately 47° N., 154° W., this locality being at the time under the influence of the Aleutian disturbance.

Winds at Honolulu.—At Honolulu the prevailing direction of the wind during May was from the northeast, with maximim velocity 25 miles from the east on the 4th. An unusually large number of *konas*, or southerly winds, was reported.

Fog.—Fog showed a distinct increase in frequency over that of April throughout the western part of the upper routes. It was reported on 20 days for the whole region between latitudes 40° and 50° N., and longitude 180° and the Japanese coast. It was most frequent between longitudes 150° and 170° E., where it formed in some 5-degree localities on approximately one-third of the days of the month. East of 180°, in these latitudes, fog occurrence diminished to three or less days per 5-degree square, except east of 160° W., where it became slightly more frequent. Between 40° and 45° N., 130° and 140° W., the whole area seems to have been mantled in fog during the first five days. Between Tatoosh Island and San Diego, 10 to 20 per cent of the days had fog, the highest percentage forming near the coast below San Francisco.

BUCKET OBSERVATIONS OF SEA-SURFACE TEMPERATURES

By GILES SLOCUM

STRAITS OF FLORIDA AND CARIBBEAN SEA

The temperatures herein published are the means of the average temperatures for the four quarters of the month, except that, in the case of the 5-degree subdivisions of the Caribbean Sea, the figures shown are the simple means of the observed temperatures with the entire month taken as a unit. Table 1 shows the lengths of the quarters for each length of month.

Table 2 shows the average temperature for the Caribbean Sea and the Straits of Florida for May of each year from 1919 to 1930, inclusive, and Table 3 summarizes the temperature for the month in the same areas, including the departures of the May, 1930, means from the 11-year means for May, 1920–1930, and the changes from the temperatures, for the preceding month of April, 1930.

The chart shows the number of observations taken during the month of May, 1930, within each 1-degree square; the mean temperature of the Straits of Florida, and of each 5-degree[1] subdivision of the Caribbean Sea; the 11-year means (1920–1930) for these areas; and the local mean time corresponding to Greenwich mean noon, at which time the mariners are instructed to make the temperature readings.

May is a month of rapid warming of the surface water in the Straits of Florida, being second only to June in this respect, while in the Caribbean Sea, the greatest upward change in the temperature takes place, on the average, during this month. The amount of this rise in temperature averages somewhat more than 1° in the Caribbean Sea, and nearly 2½° in the Straits of Florida.

During May the principal discharge from the Caribbean Sea, at the Yucatan Channel, begins to follow summer tracks, with relatively little of the water taking the direct route north of Cuba and out the Straits of Florida. A considerable bulk of the water makes instead a circuit of the entire Gulf of Mexico. Summer conditions have begun to prevail in the Mexican and Gulf States littoral, and consequently, the near-by land is slightly warmer than the sea currents over most of the route.

The water from the Caribbean, mixed with that from more local Gulf currents, finally approaches the vicinity of the Straits of Florida from the west and northwest, having been flowing at all times during the circuit, with relatively low velocity. Examination of current charts indicates that the rates of flow during May are such that the currents setting north and northwest from the Yucatan Channel at this time can hardly complete more than a minor fraction of their circuit in a month; it is therefore presumable that in the latter part of May and in early June, the current through the Straits of Florida may normally contain a minimum of direct flow from the Caribbean through the Yucatan Channel past the northwestern coast of Cuba.

Temperatures were somewhat above the average, during the month of May, 1930, in the region immediately southwest of the Leeward Islands and generally in the Caribbean Sea west of 75° W., and approximately

[1] In three cases, as indicated on the chart, the observations from small, little traveled, and unimportant areas at the outer limits of the Caribbean Sea have been treated as parts of contiguous 5-degree subdivisions.

average for the region about the Windward Islands and between Haiti and Porto Rico on the north, and the South American coast on the south, making the Caribbean Sea, as a whole, warmer than the 11-year mean at all times during the month.

TABLE 1.—*Lengths of "quarter months" used in computing mean sea-surface temperatures*

Length of month	Days of month included in quarter			
	I	II	III	IV
28 days	1–7	8–14	15–21	22–28
29 days	1–7	8–14	15–21	22–29
30 days	1–7	8–15	16–22	23–30
31 days	1–7	8–15	16–23	24–31

TABLE 2.—*Mean sea-surface temperatures in the Caribbean Sea and the Straits of Florida for May, 1919–1930*

Year	Caribbean Sea		Straits of Florida	
	Number of observations	Mean temperature	Number of observations	Mean temperature
1919 [1]	44	81.0	12	77.7
1920	180	80.2	32	78.6
1921	173	79.8	44	77.4
1922	190	79.8	76	79.2
1923	393	80.0	107	78.8
1924	328	81.1	108	79.0
1925	362	80.4	137	79.0
1926	355	81.3	124	79.0
1927	462	81.2	160	79.7
1928	380	80.7	143	77.6
1929	483	79.9	146	79.8
1930	526	81.0	158	79.6
Mean (1920–1930)		80.5		78.9

[1] Not used in computations because of insufficient data available.

The Florida Straits were also warmer than the average. Particularly noticeable was a protracted period, beginning with the second quarter of April and persisting throughout May, in which the mean temperature showed a rapid, uninterrupted, and remarkably uniform rise. Because of the rapidity of this rise, there was a rather extreme contrast between the temperature of any given quarter in May and the corresponding part of April.

TABLE 3.—*Mean sea-surface temperatures (°F.), and number of observations, May, 1930*

Quarter	Period	Caribbean Sea				Straits of Florida			
		Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month	Number of observations	Mean	Departure from 11-year mean (1920–1930)	Change from preceding month
			°F.	°F.	°F.		°F.	°F.	°F.
I	May 1–7	128	80.7			39	78.3		
II	May 8–15	122	81.1			43	79.1		
III	May 16–22	165	81.2			36	80.2		
IV	May 23–31	111	81.2			40	81.0		
Month		526	81.0	+0.5	+1.6	158	79.6	+0.7	+3.1

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1931

[For description of tables and charts, see January, 1931, REVIEW, p. 50]

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	68.6	−2.7	2 stations	96	[1]27	St. Bernard	38	24	3.35	−0.59	Highland Home	6.93	Tuskegee	0.63
Arizona	69.4	+1.5	do	113	31	Alpine	18	19	0.29	−0.05	Tucson Airport	2.16	36 stations	0.00
Arkansas	65.2	−3.9	Hope	96	27	Dutton	27	7	3.45	−1.66	Danville	6.18	Hope	0.74
California	66.3	+5.9	Greenland Ranch	114	[1]30	Madeline	23	19	1.03	−0.06	Huntington Lake	3.87	10 stations	0.00
Colorado	51.0	−1.4	Las Animas	101	[1]13	3 stations	4	[1]8	1.69	−0.05	Fremont Experiment Station.	4.95	Rifle	0.15
Florida	74.2	−1.4	2 stations	97	[1]21	Carrabelle	44	17	3.35	−0.62	Eustis	8.77	Tallahassee	0.83
Georgia	69.7	−1.9	do	98	31	Clayton	33	24	3.45	+0.02	Fort Valley	8.72	Brunswick	0.35
Idaho	55.1	+2.3	Kooskia	100	13	Obsidian	12	[1]8	0.66	−0.92	Preston	2.30	3 stations	0.00
Illinois	59.4	−3.2	Mount Carmel	94	28	La Harpe	28	7	4.25	+0.29	Anna	7.29	Galena	2.01
Indiana	59.3	−2.8	2 stations	95	[1]17	Marengo	28	8	2.96	−1.10	Boonville	6.85	Leavenworth	1.27
Iowa	57.5	−2.6	Inwood (near)	98	26	2 stations	21	7	2.96	−1.62	Denison	5.65	Rock Rapids	1.11
Kansas	60.5	−2.7	2 stations	99	[1]15	Oberlin	25	20	2.89	−0.75	Reading	8.12	Hoxie	0.57
Kentucky	62.7	−2.6	do	97	[1]29	Paducah (near)	30	9	2.59	−1.41	Jenkins	5.60	Frankfort	0.38
Louisiana	69.9	−3.7	Lake Providence	97	28	3 stations	40	13	3.24	−1.19	Angola	10.86	Minden	0.52
Maryland-Delaware	62.3	−0.1	4 stations	95	[1]29	Oakland, Md	23	[1]1	4.50	+1.13	Western Port, Md	7.64	Great Falls, Md	2.20
Michigan	53.7	−0.1	Black Lake	95	28	Wolverine	13	1	3.21	+0.02	Grayling	5.24	Marquette	1.65
Minnesota	53.7	−0.8	Beardsley	98	16	Beardsley	17	7	2.29	−0.77	Pine River Dam	5.25	Bird Island	0.92
Mississippi	68.6	−3.0	Greenwood	97	29	Port Gibson	41	13	3.99	−0.45	Poplarville	9.23	Austin	1.85
Missouri	61.0	−3.4	2 stations	96	16	4 stations	29	7	4.55	−0.12	Mexico	8.05	Caruthersville	1.62
Montana	53.7	+2.6	do	99	[1]13	Loweth	7	18	0.92	−1.23	Mystic Lake	3.09	Red Lodge (near)	T.
Nebraska	57.5	−1.6	Culbertson	102	15	Gordon	12	21	2.23	−1.30	Lincoln (University Farm).	7.17	Sutherland	0.10
Nevada	60.3	+3.9	Las Vegas	108	31	Zorra Vista Ranch	19	21	0.38	−0.43	Marlette Lake	1.51	Searchlight	0.00
New England	56.1	+1.2	3 stations	95	[1]29	2 stations	20	[1]1	4.31	+0.89	East Hartland, Conn.	8.70	Lincoln, Me.	1.23
New Jersey	60.4	+0.1	Elizabeth	97	[1]29	Layton	21	1	3.73	−0.07	Dover	6.33	Tuckerton	0.77
New Mexico	58.0	−1.2	3 stations	100	25	2 stations	10	11	1.07	−0.18	Grady (near)	6.52	7 stations	0.00
New York	57.1	+1.4	Troy	96	30	North Lake	18	1	4.77	+1.25	Oswego	7.47	Chazy	2.07
North Carolina	64.9	−1.9	Louisburg	93	31	Mount Mitchell	22	24	4.88	+0.70	Mount Holly	8.57	Marshall	1.82
North Dakota	53.1	+0.3	Amenia	100	[1]15	Washburn	10	5	1.41	−0.99	Hillsboro	3.40	Mohall	T.
Ohio	59.1	−1.1	3 stations	95	[1]28	Millport	24	1	3.07	−0.58	Kinsman	5.61	Toledo	1.17
Oklahoma	64.7	−3.2	2 stations	100	[1]15	2 stations	30	[1]12	2.91	−1.71	Pryor	8.38	Marlow	0.67
Oregon	57.4	+4.3	Umatilla	104	13	Blitzen	11	19	0.66	−0.92	Welches	3.64	Big Eddy	0.00
Pennsylvania	59.8	+0.4	Arendtsville	98	29	2 stations	19	1	5.28	+1.38	Center Hall	12.97	Lancaster	2.33
South Carolina	68.0	−2.8	3 stations	95	[1]18	Caesar's Head	33	24	4.74	+1.10	Clemson College	10.39	Charleston	1.12
South Dakota	55.9	−0.3	Aberdeen	103	15	Camp Crook	15	21	2.02	−1.04	Watertown	8.16	Brookings	0.68
Tennessee	64.2	−2.5	Cedar Hill	97	28	Crossville	28	8	2.84	−1.39	Elkmont	7.04	Cedar Hill	1.25
Texas	69.3	−3.8	2 stations	104	[1]19	Romero	33	12	2.40	−1.31	Laredo	9.82	Clint	0.02
Utah	55.5	+0.1	St. George	100	31	Woodruff	12	[1]11	0.87	−0.41	Riverdale	2.31	Emery	0.00
Virginia	63.4	−0.4	Woodstock	97	29	Dante	30	24	5.15	+1.57	Callaville	8.26	Mount Weather	2.61
Washington	57.7	+3.3	Wahluke	103	30	Paradise Inn	19	7	1.12	−0.82	Big Four	6.91	4 stations	0.00
West Virginia	60.6	−1.0	Williamson	98	29	Bayard	23	[1]1	5.09	+1.04	Davis	9.59	Robertsburg	2.68
Wisconsin	53.5	−1.3	2 stations	92	[1]15	Big St. Germain Dam.	15	3	1.86	−1.75	Superior	3.78	Mellen	0.58
Wyoming	48.9	−0.3	Colony	96	25	Dome Lake	0	20	1.79	−0.37	Salt Creek (near)	4.76	Green River	0.13
Alaska [April]	28.8	+0.1	2 stations	75	[1]6	Fort Yukon	−22	3	1.56	−0.12	Hydaburg	14.67	McKinley Park	T.
Hawaii	72.4	+0.6	Mahukona	92	22	Kanalohuluhulu	44	[1]1	5.80	−0.18	Kailua (Mauka)	19.20	Waiopai Ranch	0.00
Porto Rico	78.7	+1.5	Dorado	97	15	Guineo Reservoir	56	16	12.00	+5.45	San Cristobal	20.09	Rio Grande	2.35

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles									0–10	In.	In.
New England							56.3	+1.6										77	3.91	+0.8											5.6		
Eastport	78	67	85	29.86	29.94	−0.02	48.7	+1.0	83	29	56	32	1	41	34	45	41	78	2.57	−0.4	13	6,692	s.	33	ne.	11	5	11	15	7.0	T.	0.0
Greenville, Me.	1,070	6	----	28.77	29.94	----	52.8	----	88	20	64	24	2	41	38	----	----	----	4.02	----	15	5,091	se.	26	----	29	9	10	12	----	3.0	0.0
Portland, Me.	103	82	117	29.79	29.91	−.06	54.8	+1.5	91	29	63	33	1	47	30	48	43	70	3.84	+0.4	12	5,837	s.	26	e.	10	14	7	10	5.0	0.0	0.0
Concord	289	70	79	29.62	29.93	−.05	56.8	+2.5	92	29	69	28	2	44	44	----	----	----	2.97	0.0	14	3,685	se.	27	e.	10	15	5	11	5.0	0.0	0.0
Burlington	403	11	48	29.47	29.90	−.07	56.4	−0.1	85	20	66	31	4	46	36	----	----	----	2.20	−0.6	16	6,194	s.	36	s.	19	9	5	17	6.4	0.0	0.0
Northfield	876	12	60	28.96	29.94	−.03	53.6	+0.8	87	29	66	26	2	41	44	51	48	82	3.46	+0.7	16	4,274	s.	27	s.	2	8	9	14	6.3	0.0	0.0
Boston	125	106	165	29.80	29.94	−.04	60.3	+3.2	94	29	70	37	1	50	32	53	47	68	4.51	+1.3	10	5,238	sw.	24	nw.	3	9	12	10	5.5	0.0	0.0
Nantucket	12	14	90	29.94	29.94	−.05	54.6	+2.3	81	29	62	39	1	48	26	51	48	84	4.24	+1.4	15	10,358	sw.	36	ne.	13	8	14	9	5.2	0.0	0.0
Block Island	26	11	46	29.91	29.94	−.05	54.4	+1.6	81	30	60	38	2	48	22	51	49	86	3.79	+0.3	15	10,479	sw.	41	ne.	14	12	9	10	5.2	0.0	0.0
Providence	160	215	251	29.77	29.94	−.04	60.0	+1.5	93	29	69	33	1	50	35	53	48	69	4.07	+1.1	14	7,051	nw.	40	nw.	16	12	11	8	5.1	0.0	0.0
Hartford	159	122	----	29.76	29.94	−.04	60.0	+2.5	92	29	70	36	1	50	36	----	----	----	5.50	+1.9	13	----	s.	----	----	----	9	7	15	5.7	0.0	0.0
New Haven	106	74	153	29.83	29.94	−.05	59.4	+1.5	93	29	68	38	1	50	35	54	50	77	5.90	+2.2	16	5,672	s.	28	sw.	16	9	11	11	5.8	0.0	0.0
Middle Atlantic States							62.1	+0.1										72	4.34	+0.9										5.7		
Albany	97	107	115	29.82	29.92	−.06	60.4	+1.1	93	29	70	33	1	50	34	53	47	68	5.92	+3.0	13	4,343	s.	23	se.	2	13	8	10	4.8	T.	0.0
Binghamton	871	10	84	29.00	29.93	−.05	58.0	+0.6	89	29	70	28	1	46	41	----	----	----	4.77	+1.5	16	3,568	nw.	19	w.	16	8	5	18	6.4	T.	0.0
New York	314	414	454	29.60	29.93	−.06	60.4	−0.2	89	30	68	40	1	52	24	53	48	70	3.93	+0.7	13	9,116	s.	42	w.	16	8	12	11	5.9	0.0	0.0
Bellefonte	1,050	5	36	28.82	29.92	----	57.7	----	89	28	70	23	1	46	44	52	47	71	8.03	----	17	----	sw.	34	s.	30	4	13	14	6.7	0.0	0.0
Harrisburg	374	94	104	29.55	29.95	−.03	62.3	+0.5	91	29	72	37	1	53	33	54	48	65	3.75	+0.3	15	4,407	w.	27	s.	30	7	16	8	5.3	0.0	0.0
Philadelphia	114	123	367	29.83	29.95	−.04	64.2	+1.3	91	30	73	43	1	55	30	55	50	66	4.44	+1.2	12	8,396	sw.	35	sw.	16	7	12	12	6.3	0.0	0.0
Reading	325	81	98	29.59	29.94	----	62.6	+0.1	91	29	73	35	1	52	34	54	48	64	3.66	0.0	14	4,050	se.	20	se.	22	8	14	9	5.7	0.0	0.0
Scranton	805	111	119	29.08	29.93	−.05	59.6	+0.2	91	29	72	30	1	48	40	53	47	65	4.03	+0.8	16	4,006	sw.	26	sw.	20	9	12	10	5.5	0.0	0.0
Atlantic City	52	37	172	29.89	29.95	−.03	58.0	−0.1	83	16	64	41	5	52	26	54	51	80	1.43	−1.6	13	10,990	s.	40	ne.	13	10	11	10	5.4	0.0	0.0
Cape May	17	13	49	----	----	----	59.2	+0.6	82	16	67	36	5	51	27	55	52	84	2.76	−0.2	14	----	se.	----	----	----	6	13	12	----	0.0	0.0
Sandy Hook	22	10	55	29.90	29.92	----	58.5	----	89	29	66	43	1	52	30	54	51	81	4.03	+0.3	13	8,307	s.	34	sw.	20	8	12	11	5.5	0.0	0.0
Trenton	190	159	183	29.74	29.94	----	61.8	+0.7	92	30	72	38	1	51	34	56	52	75	4.00	+0.9	13	6,066	sw.	30	w.	16	8	13	10	6.0	0.0	0.0
Baltimore	123	100	215	29.80	29.93	−.06	65.2	+0.8	88	30	74	45	1	57	30	57	51	66	5.80	+2.3	12	6,960	se.	36	sw.	16	9	9	13	6.1	0.0	0.0
Washington	112	62	85	29.82	29.94	−.06	65.1	+1.4	92	30	75	40	1	55	34	56	51	65	4.84	+1.1	12	3,951	s.	24	nw.	24	7	13	11	5.3	0.0	0.0
Cape Henry	18	8	54	29.93	29.95	----	63.9	−0.3	88	16	72	47	4	56	30	59	56	78	3.75	+0.2	13	6,958	sw.	31	nw.	23	8	13	10	5.5	0.0	0.0
Lynchburg	681	153	188	29.21	29.94	−.06	65.0	−2.3	92	29	76	41	5	54	35	58	54	72	5.93	+2.3	13	4,262	w.	40	nw.	22	11	10	10	5.3	0.0	0.0
Norfolk	91	170	205	29.87	29.97	−.03	66.0	−0.2	88	29	75	46	24	57	29	58	54	72	4.62	+0.8	15	7,988	s.	34	nw.	22	9	13	9	5.4	0.0	0.0
Richmond	144	11	52	29.80	29.96	−.03	65.5	−1.0	88	29	76	41	5	55	31	59	55	78	5.64	+1.8	15	4,778	sw.	39	w.	9	10	8	13	5.5	0.0	0.0
Wytheville	2,304	49	55	27.60	29.94	−.05	59.2	−2.2	87	29	70	41	9	49	35	53	48	72	4.85	+1.2	18	3,718	w.	22	nw.	22	9	11	11	5.7	0.0	0.0
South Atlantic States							68.5	−1.7										71	4.14	+0.6										4.9		
Asheville	2,253	89	104	27.65	29.97	−.02	61.8	−0.8	88	29	73	36	24	50	38	54	49	69	2.20	−1.2	13	5,225	nw.	26	nw.	23	9	16	6	5.0	0.0	0.0
Charlotte	779	55	62	29.14	29.96	−.03	67.2	−1.7	90	31	78	43	24	57	29	58	53	66	6.53	+2.9	13	2,761	sw.	19	nw.	22	10	10	11	5.4	0.0	0.0
Greensboro	886	6	56	29.02	29.98	----	64.6	----	88	29	76	38	24	52	30	57	53	74	5.97	----	12	5,214	sw.	35	sw.	7	8	13	10	5.7	0.0	0.0
Hatteras	11	5	50	29.96	29.97	−.03	67.1	−1.6	79	16	74	54	24	60	22	62	60	82	4.35	+0.6	12	7,716	sw.	30	nw.	23	18	7	6	3.8	0.0	0.0
Raleigh	376	103	146	29.56	29.96	−.03	66.8	−1.7	88	29	77	41	5	56	31	59	54	69	6.16	+2.4	9	5,175	sw.	32	se.	7	9	12	10	5.4	0.0	0.0
Wilmington	78	81	91	29.91	29.99	−.02	68.7	−2.1	86	16	78	48	24	60	26	62	59	75	3.62	+0.2	11	4,777	sw.	20	w.	22	12	11	8	4.6	0.0	0.0
Charleston	48	11	92	29.93	29.98	−.03	71.4	−1.3	88	17	79	53	24	64	23	64	61	74	1.12	−1.9	7	6,861	s.	32	e.	4	12	9	10	5.1	0.0	0.0
Columbia, S. C.	351	41	57	29.60	29.97	−.03	68.9	−3.0	90	18	79	46	24	59	31	60	54	66	3.75	+0.7	13	4,392	s.	19	w.	11	10	16	5	4.9	0.0	0.0
Due West	711	10	55	29.23	30.00	----	67.0	----	89	31	78	43	24	56	31	----	----	----	3.17	----	13	5,534	sw.	31	w.	31	12	11	8	4.9	0.0	0.0
Greenville, S. C.	1,039	139	146	28.88	29.96	----	66.2	−1.0	88	18	76	46	8	57	29	57	51	64	5.73	+1.7	14	5,551	s.	36	w.	22	13	10	8	4.6	0.0	0.0
Augusta	182	62	77	29.76	29.95	−.04	70.3	−2.1	91	26	81	48	24	59	36	63	59	73	3.51	+0.5	15	3,542	nw.	20	n.	26	11	13	7	4.3	0.0	0.0
Savannah	65	150	194	29.90	29.97	−.03	72.0	−1.4	91	22	81	52	24	63	28	64	60	73	1.88	−1.1	8	7,236	s.	28	s.	7	12	6	13	5.0	0.0	0.0
Jacksonville	43	209	245	29.93	29.98	−.02	73.2	−1.8	89	22	81	57	14	65	23	65	61	72	5.93	+1.9	11	6,954	s.	29	nw.	27	13	8	10	4.8	0.0	0.0
Florida Peninsula							77.1	−0.1										73	3.33	−0.9										4.8		
Key West	22	10	64	29.93	29.95	−.02	78.6	−0.5	87	12	84	69	9	73	16	72	69	75	2.41	−1.1	4	6,041	e.	25	w.	13	12	15	4	4.2	0.0	0.0
Miami	25	124	168	29.94	29.97	−.02	77.0	+0.6	87	12	82	59	15	72	20	70	66	71	4.34	−1.9	14	6,269	ne.	26	nw.	14	8	12	11	5.5	0.0	0.0
Tampa	35	79	197	29.94	29.98	−.01	75.8	−0.5	89	1	84	60	25	67	26	68	64	73	3.24	+0.2	9	6,337	e.	30	n.	11	12	11	8	4.7	0.0	0.0
Titusville	44	5	----	29.94	29.99	----	75.8	----	92	11	85	56	14	67	27	----	----	----	3.42	----	9	----	ne.	----	----	----	14	9	8	4.8	0.0	0.0
East Gulf States							69.6	−2.8										69	2.95	−0.9										4.3		
Atlanta	1,173	190	198	28.75	29.98	−.01	66.6	−3.3	89	30	76	46	24	57	29	57	50	61	2.77	−0.7	9	6,650	w.	25	w.	22	14	7	10	4.6	0.0	0.0
Macon	370	78	87	29.58	29.97	−.02	69.2	−3.1	92	31	81	46	24	58	37	60	54	62	4.96	+2.0	9	3,796	s.	19	s.	19	14	9	8	4.4	0.0	0.0
Thomasville	273	49	103	29.68	29.97	−.02	72.4	−1.6	92	31	84	53	13	61	29	63	59	69	4.05	+0.4	8	4,469	sw.	24	s.	4	8	18	5	4.6	0.0	0.0
Apalachicola	36	11	51	29.94	29.98	----	71.8	----	88	27	79	55	24	64	23	66	62	74	1.16	−2.2	7	5,121	sw.	35	e.	27	20	7	4	2.7	0.0	0.0
Pensacola	56	149	185	29.92	29.98	−.01	71.0	−2.9	85	31	77	54	13	65	19	64	61	73	1.83	−1.5	7	7,652	sw.	29	e.	27	11	17	3	4.3	0.0	0.0
Anniston	741	9	57	29.21	30.00	+.01	66.6	−1.8	91	27	79	40	24	54	38	----	----	----	3.29	−0.6	10	2,941	nw.	14	w.	10	17	7	7	4.2	0.0	0.0
Birmingham	700	11	48	29.22	29.98	.00	67.6	−3.5	90	27	79	47	13	57	30	59	54	68	2.72	−1.2	9	4,019	n.	23	s.	19	13	11	7	4.5	0.0	0.0
Mobile	57	125	161	29.91	29.98	−.01	71.6	−2.8	91	27	80	52	13	63	26	65	61	76	3.63	−0.7	9	6,097	sw.	33	nw.	20	10	12	9	4.8	0.0	0.0
Montgomery	223	100	112	29.73	29.98	−.01	70.0	−3.4	90	27	80	50	24	60	28	60	55	64	2.55	−1.3	9	4,169	w.	27	se.	20	12	12	7	4.6	0.0	0.0
Corinth	469	6	----	----	----	----	67.2	----	95	27	79	43	8	56	38	----	----	----	3.44	----	9	----	se.	----	----	----	11	15	5	----	0.0	0.0
Meridian	375	87	95	29.58	29.97	−.01	68.6	−2.7	91	27	80	47	24	58	34	60	54	64	2.67	−1.6	9	3,629	sw.	23	w.	11	13	13	5	4.3	0.0	0.0
Vicksburg	247	65	73	29.72	30.00	+.03	69.0	−3.9	92	28	78	51	12	59	26	62	58	71	3.29	−1.0	7	4,119	nw.	21	w.	11	14	11	6	3.9	0.0	0.0
New Orleans	53	76	84	29.92	29.97	.00	73.4	−2.0	90	30	82	58	13	65	24	67	64	77	2.48	−2.1	9	3,634	sw.	17	nw.	20	11	15	5	4.3	0.0	0.0
West Gulf States							69.8	−3.6										72	1.96	−2.1										5.0		
Shreveport	249	77	93	29.71	29.98	+.03	69.0	−4.6	90	28	79	45	7	59	28	62	58	73	1.17	−3.0	8	3,893	s.	16	w.	11	10	14	7	4.9	0.0	0.0
Bentonville	1,303	11	44	28.58	29.94	+.01	61.4	−5.0	89	16	72	37	7	51	34	----	----	----	5.42	----	9	3,170	s.	17	w.	9	21	4	6	----	0.0	0.0
Fort Smith	457	79	94	29.47	29.95	+.02	65.5	−4.1	90	16	76	41	7	56	31	58	52	66	4.35	−0.5	11	5,259	e.	36	w.	29	12	10	9	5.1	0.0	0.0
Little Rock	357	136	153	29.59	29.96	+.01	66.0	−4.3	88	16	75	46	7	57	27	58	52	64	2.07	−2.7	11	6,328	sw.	26	sw.	5	9	13	9	5.5	0.0	0.0
Austin	605	136	148	29.32	29.95	----	71.6	−3.0	90	15	82	48	7	61	36	63	58	67	0.58	−4.1	5	5,600	s.	26	ne.	11	8	15	8	5.1	0.0	0.0
Brownsville	57	83	100	29.87	29.93	----	75.3	−3.3	88	6	82	62	7	68	22	69	67	82	0.86	−1.4	11	6,962	se.	32	nw.	7	8	14	9	5.4	0.0	0.0
Corpus Christi	20	11	78	29.93	29.95	+.05	73.6	−2.6	85	31	79	57	7	68	23	68	66	82	2.72	−0.5	10	8,148	se.	37	nw.	20	6	13	12	6.3	0.0	0.0
Dallas	512	220	227	29.43	29.98	----	67.4	----	90	15	76	44	7	58	32	----	----	----	3.01	−1.5	7	8,308	se.	31	w.	5	13	11	7	4.0	0.0	0.0
Fort Worth	670	106	114	29.25	29.96	+.05	68.5	−3.8	91	15	78	45	7	59	32	59	54	65	2.42	−2.2	7	5,691	nw.	28	se.	21	8	9	14	5.8	0.0	0.0
Galveston	54	106	114	29.94	30.00	+.06	71.8	−3.0	83	3	76	56	7	67	17	66	64	80	3.14	−0.3	5	6,712	se.	26	se.	19	6	17	8	5.3	0.0	0.0
Groesbeck	461	11	56	29.49	29.97	----	67.8	----	85	15	77	45	7	58	30	----	----	----	3.03	−1.0	8	6,745	n.	30	n.	21	12	13	3	4.6	0.0	0.0
Houston	138	292	314	29.84	29.99	----	72.1	−3.4	85	4	80	52	7	64	25	----	----	----	0.37	−4.1	5	7,412	se.	30	n.	11	13	8	10	5.1	0.0	0.0
Palestine	510	64	72	29.46	29.99	+.06	68.5	−4.2	86	25	78	44	7	59	28	61	57	71	2.16	−2.4	8	4,691	s.	20	nw.	12	13	11	7	4.6	0.0	0.0
Port Arthur	34	58	66	29.95	29.99	----	72.2	----	88	29	80	53	12	65	23	----	----	----	1.20	−2.9	6	4,898	s.	23	n.	20	17	6	8	4.2	0.0	0.0
San Antonio	693	242	301	29.22	29.93	+.03	72.5	−2.6	90	14	82	52	7	63	30	63	58	66	1.36	−1.8	11	8,116	n.	34	n.	19	8	19	4	4.9	0.0	0.0
Taylor	571	38	51	29.40	29.99	+.08	71.0	−3.3	90	15	82	45	7	60	37	----	----	----	0.97	−3.0	6	5,799	s.	23	n.	6	11	16	4	4.0	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*		*°F.*	*°F.*		*°F.*	*°F.*	*°F.*	*°F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
							62.2	**−2.7**										**66**	**3.28**	**−0.5**										**5.8**		
Chattanooga	762	190	215	29.15	29.95	−0.04	66.7	−2.1	90	27	77	41	8	57	32	57	50	59	1.77	−2.0	8	5,809	sw.	27	sw.	10	11	14	6	5.0	0.0	0.0
Knoxville	995	102	111	28.92	29.96	−.03	66.0	−1.2	91	29	77	41	24	55	31	57	51	64	3.71	0.0	12	4,329	sw.	31	s.	11	7	15	9	5.8	0.0	0.0
Memphis	399	76	97	29.53	29.95	−.01	66.4	−4.2	91	28	75	45	7	58	27	57	51	62	2.30	−1.9	11	5,914	sw.	28	sw.	10	12	8	11	5.0	0.0	0.0
Nashville	546	168	191	29.40	29.98	.00	64.8	−3.4	91	28	74	42	8	55	32	57	51	65	1.92	−2.0	11	6,290	nw.	36	nw.	22	8	14	9	5.5	0.0	0.0
Lexington	989	193	230	28.92	29.98	−.01	61.2	−3.1	88	29	70	39	3	52	34				1.13	−2.7	9	8,438	sw.	35	sw.	20	13	6	12	5.2	0.0	0.0
Louisville	525	188	234	29.38	29.96	−.02	62.4	−4.2	89	29	72	40	8	53	32	55	50	67	1.94	−1.8	9	7,010	s.	36	nw.	19	8	9	14	5.9	0.0	0.0
Evansville	431	76	116	29.48	29.95	−.02	62.8	−3.9	90	17	72	38	7	53	29	56	51	68	2.37	−1.5	13	6,295	s.	36	s.	19	9	10	12	5.9	0.0	0.0
Indianapolis	822	194	230	29.05	29.94	−.03	59.4	−3.5	87	28	69	37	7	50	30	51	44	63	2.51	−1.4	12	7,668	sw.	27	sw.	18	8	9	14	6.1	0.0	0.0
Royal Center	736	11	55	29.13	29.93	------	55.8	------	87	28	67	30	3	44	36				3.81	−0.2	11	6,846	s.	26	se.	5	12	5	14	5.3	0.0	0.0
Terre Haute	575	96	129	29.32	29.93	------	60.2	------	89	28	70	38	7	50	34	53	48	69	3.24	−0.6	8	6,197	s.	30	sw.	16	8	8	15	6.2	0.0	0.0
Cincinnati	627	11	51	29.27	29.95	−.04	60.6	−2.5	89	29	71	37	3	50	33	53	48	67	4.47	+0.8	12	4,433	sw.	22	sw.	6	9	9	13	6.1	0.0	0.0
Columbus	822	216	230	29.07	29.94	−.04	59.8	−2.5	89	28	70	38	1	50	30	52	46	64	2.96	−0.6	14	7,046	s.	32	w.	2	7	14	10	5.9	0.0	0.0
Dayton	899	137	173	28.99	29.94	------	59.6	−3.0	87	29	69	37	3	50	33	53	47	65	2.11	−1.5	15	5,693	sw.	26	sw.	20	7	15	9	6.1	0.0	0.0
Elkins	1,947	59	67	27.94	29.97	−.03	58.0	−1.2	86	28	70	29	4	46	45	51	47	73	7.90	+3.8	19	3,498	w.	25	nw.	2	4	9	18	7.1	0.0	0.0
Parkersburg	637	77	82	29.31	29.97	−.02	62.1	−1.7	92	28	72	38	4	52	38	54	48	65	4.82	+1.4	17	3,431	nw.	24	nw.	2	9	7	15	6.3	0.0	0.0
Pittsburgh	842	353	410	29.04	29.93	−.06	60.8	−1.6	88	29	71	36	4	50	37	53	48	66	5.46	+2.2	19	6,421	sw.	33	nw.	23	6	13	12	6.1	0.0	0.0
Lower Lake Region							**57.5**	**0.0**										**67**	**3.45**	**+0.2**										**5.5**		
Buffalo	767	247	280	29.08	29.90	−.07	55.6	+1.0	83	6	64	34	1	48	39	49	43	69	2.74	−0.4	18	9,233	sw.	48	w.	30	10	11	10	5.4	0.0	0.0
Canton	448	10	61	29.41	29.88	------	55.7	−0.5	85	20	65	27	1	46	40				3.53	+0.5	18	6,159	sw.	36	sw.	19	8	10	13	5.9	0.0	0.0
Ithaca	836	74	100	28.99	29.91	------	58.4	+0.9	92	29	70	30	1	47	40	51	46	68	4.48	+1.1	15	5,992	nw.	30	se.	7	10	8	13	5.8	0.8	0.0
Oswego	335	71	85	29.54	29.90	−.07	55.2	0.0	86	28	64	32	1	47	39	50	45	71	7.47	+4.4	13	5,747	w.	24	nw.	30	7	10	14	6.2	T.	0.0
Rochester	523	86	102	29.35	29.92	−.05	58.8	+1.7	89	28	68	32	1	49	40	50	44	65	5.32	+2.4	15	5,465	sw.	27	w.	20	9	9	13	5.8	T.	0.0
Syracuse	596	65	79	29.28	29.92	−.06	59.2	+1.9	90	29	68	34	1	50	38				4.42	+1.4	15	4,396	s.	20	s.	16	11	7	13	5.8	T.	0.0
Erie	714	130	166	29.15	29.92	−.06	57.2	+0.4	86	18	66	33	1	49	38	51	46	69	2.83	−0.6	16	8,642	w.	38	s.	19	13	8	10	4.9	0.0	0.0
Cleveland	762	267	337	29.11	29.93	−.05	57.5	−0.4	86	28	65	36	1	50	36	50	44	65	2.36	−0.8	16	8,891	n.	36	nw.	23	8	10	13	6.0	0.0	0.0
Sandusky	629	5	67	29.26	29.94	−.04	58.4	−0.8	90	28	68	36	24	49	40				2.10	−1.0	15	5,436	sw.	22	sw.	16	7	11	13	5.8	0.0	0.0
Toledo	628	208	243	29.25	29.93	−.04	58.4	−1.0	88	28	68	37	3	49	38	50	43	64	1.17	−2.3	15	8,561	sw.	31	sw.	19	11	12	8	4.7	0.0	0.0
Fort Wayne	856	100	119	29.01	29.93	------	57.1	−3.1	88	28	68	36	24	46	38	51	46	68	2.00	−1.8	13	6,350	sw.	25	nw.	2	12	7	12	5.2	0.0	0.0
Detroit	730	218	258	29.15	29.94	−.03	58.4	+0.4	90	28	69	39	1	48	42	50	45	68	2.32	−0.9	13	6,014	sw.	28	sw.	20	14	10	7	4.2	0.0	0.0
Upper Lake Region							**52.3**	**−0.5**										**71**	**2.88**	**−0.3**										**5.8**		
Alpena	609	13	92	29.24	29.91	−.06	52.0	+1.5	92	28	62	30	3	42	39	47	42	73	2.74	−0.3	12	7,068	se.	27	nw.	2	11	8	12	5.6	T.	0.0
Escanaba	612	54	60	29.24	29.91	−.06	49.0	−0.6	87	15	56	26	30	42	30	44	39	71	3.06	+0.1	9	6,595	s.	30	n.	2	11	7	13	5.6	T.	0.0
Grand Haven	632	54	89	29.23	29.91	−.05	51.6	−3.9	79	28	60	31	3	43	32	47	42	72	2.88	−0.3	11	6,867	w.	26	sw.	18	12	2	17	6.0	0.0	0.0
Grand Rapids	707	70	244	29.15	29.92	−.05	56.0	−2.0	91	28	66	31	3	46	35	49	42	66	3.23	−0.2	14	7,066	sw.	38	sw.	18	11	5	15	6.2	0.0	0.0
Houghton	668	64	99	29.17	29.90	−.07	49.2	−0.3	87	15	59	28	3	40	41				2.80	−0.3	13	6,427	w.	33	nw.	15	8	9	14	6.1	T.	0.0
Lansing	878	6	88	28.97	29.91	------	55.2	−1.7	87	28	66	30	3	44	38	50	46	75	3.71	+0.3	14	5,762	s.	21	nw.	2	10	9	12	5.4	0.0	0.0
Ludington	637	60	66	29.22	29.91	------	50.0	−2.2	74	27	57	32	3	43	26	46	42	76	2.61	−0.4	11	6,314	n.	26	s.	1	14	4	13	5.1	0.0	0.0
Marquette	734	77	111	29.10	29.90	−.07	50.0	+1.0	88	15	59	30	3	41	44	44	39	71	1.65	−1.3	14	7,052	nw.	34	sw.	1	8	5	18	6.9	T.	0.0
Port Huron	638	70	120	29.22	29.91	−.06	55.0	−0.2	86	29	64	34	1	46	39	48	43	69	1.87	−1.1	14	7,535	s.	27	w.	16	10	12	9	5.2	0.0	0.0
Sault Sainte Marie	614	11	52	29.22	29.92	−.03	50.7	+1.7	87	28	61	29	3	40	35	45	40	72	3.49	+0.5	13	5,200	nw.	24	nw.	25	8	15	8	5.2	0.1	0.0
Chicago	673	7	131	29.20	29.92	−.04	55.6	−1.9	87	28	63	40	7	48	29	49	44	71	5.08	+1.5	9	6,654	ne.	27	sw.	18	12	7	12	5.3	0.0	0.0
Green Bay	617	109	141	29.23	29.88	−.07	54.4	−0.5	84	28	64	30	3	44	34	47	41	67	1.08	−2.4	10	6,917	s.	30	ne.	16	5	9	17	7.0	0.0	0.0
Milwaukee	681	125	221	29.18	29.91	−.05	53.0	−1.1	85	28	61	36	3	45	33	47	42	71	1.70	−1.6	9	8,216	n.	36	w.	18	11	8	12	5.6	T.	0.0
Duluth	1,133	5	47	28.71	29.93	−.03	50.4	+3.1	88	15	60	30	6	40	37	43	38	69	4.51	+1.3	11	7,806	ne.	36	ne.	10	12	6	13	5.4	T.	0.0
North Dakota							**53.6**	**−0.5**										**53**	**1.50**	**−1.0**										**4.9**		
Moorhead	940	50	58	28.89	29.90	−.04	53.2	−1.9	94	15	66	24	7	41	41	45	36	57	1.95	−0.9	9	6,823	n.	33	nw.	27	11	7	13	5.9	1.2	0.0
Bismarck	1,674	8	57	28.14	29.92	.00	54.4	−0.1	93	25	68	23	20	41	42	44	34	53	1.94	−0.4	8	7,316	n.	36	w.	18	15	9	7	4.3	0.1	0.0
Devils Lake	1,478	11	44	28.34	29.92	−.02	51.4	−1.2	86	14	64	24	5	38	40	43	34	57	1.42	−0.6	11	7,707	n.	42	ne.	27	13	7	11	5.3	0.5	0.0
Ellendale	1,457	10	56	28.36	29.93	------	52.2	------	93	15	65	22	6	39	42				1.71	−1.4	8	11,077	n.	46	n.	27	14	4	13	5.4	T.	0.0
Grand Forks	833	12	67				52.4	------	92	26	66	22	6	39	43	44			2.87	------	8	------	nw.	38	nw.	1	19	3	9	----	0.9	0.0
Williston	1,878	41	48	27.95	29.92	−.01	55.2	+1.2	93	25	69	25	6	41	44	43	31	46	0.47	−1.6	4	6,011	n.	39	w.	18	17	8	6	3.5	0.5	0.0
Upper Mississippi Valley							**58.5**	**−3.0**										**66**	**2.91**	**−1.1**										**5.7**		
Minneapolis	918	102	208	28.89	29.87	------	56.1	−1.6	91	15	66	30	6	46	34				1.35	−2.3	8	8,157	n.	39	nw.	15	8	5	18	6.4	T.	0.0
St. Paul	837	114	149	28.99	29.89	−.05	56.2	−1.7	90	15	67	32	6	46	34				1.08	−2.2	9	6,372	ne.	32	nw.	15	12	7	12	5.5	0.0	0.0
La Crosse	714	11	48	29.12	29.89	−.05	56.0	−3.3	88	27	67	31	23	45	37	49	42	64	2.15	−1.6	10	3,008	nw.	16	sw.	15	9	8	14	5.8	0.0	0.0
Madison	974	70	78	28.86	29.90	−.06	54.9	−2.7	84	27	64	34	7	46	36	48	42	66	1.74	−2.1	12	5,264	s.	23	ne.	16	11	5	15	6.1	0.0	0.0
Wausau	1,247	4	62	28.57	29.91	------	54.0	------	84	15	66	28	23	42	38				0.61	−3.1	8	4,417	n.	21	sw.	1	14	6	11	5.3	0.0	0.0
Charles City	1,015	10	51	28.84	29.92	−.02	55.4	−2.4	90	27	67	31	6	44	39	48	40	61	2.73	−1.6	10	4,396	nw.	22	s.	26	13	7	11	4.7	0.0	0.0
Davenport	606	71	79	29.26	29.91	−.04	58.4	−2.9	88	27	68	35	7	48	37	50	43	62	3.21	−0.7	12	6,223	nw.	30	sw.	5	11	7	13	5.7	0.0	0.0
Des Moines	861	5	99	29.01	29.91	−.02	59.2	−2.1	90	27	71	28	7	48	34	50	43	60	2.68	−1.9	8	6,814	nw.	34	s.	24	10	9	12	5.6	0.0	0.0
Dubuque	700	81	96	29.16	29.90	−.05	56.8	−3.5	87	27	66	34	23	47	37	49	43	65	2.00	−2.2	9	3,889	s.	20	s.	24	10	6	15	6.0	0.0	0.0
Keokuk	614	64	78	29.26	29.93	−.01	59.4	−4.4	88	16	69	32	7	50	32	52	46	64	4.27	+0.3	12	4,363	sw.	19	w.	20	11	9	11	5.4	0.0	0.0
Cairo	358	87	93	29.56	29.94	−.02	64.0	−4.4	91	28	73	43	7	55	29	57	53	72	2.99	−0.7	11	5,828	s.	28	w.	9	3	11	17	6.9	0.0	0.0
Peoria	609	11	45	29.27	29.93	−.03	58.2	−3.1	87	27	68	36	7	48	33	52	47	70	5.14	+1.1	12	3,811	s.	18	w.	29	13	6	12	5.0	0.0	0.0
Springfield, Ill.	636	5	191	29.24	29.92	−.03	60.6	−2.6	91	28	71	35	7	50	33	54	50	72	4.87	+0.5	12	7,762	sw.	34	s.	24	11	10	10	5.6	0.0	0.0
Hannibal	534	74	109	29.35	29.92	−.02	60.1	−3.5	88	27	70	35	7	51	31				5.26	+0.9	14	5,368	sw.	26	sw.	24	8	11	12	5.7	0.0	0.0
St. Louis	568	265	303	29.33	29.93	−.02	62.8	−4.1	91	16	72	40	6	54	31	54	49	65	3.61	−0.7	12	8,235	sw.	36	sw.	18	13	7	11	5.2	0.0	0.0
Missouri Valley							**58.9**	**−2.5**										**69**	**3.44**	**−0.5**										**4.7**		
Columbia, Mo.	784	6	84	29.10	29.93	−.01	60.4	−3.9	89	17	71	33	7	50	35				6.45	+2.0	13	4,775	s.	22	w.	29	12	7	12	5.5	0.0	0.0
Kansas City	963	161	181	28.90	29.93	+.01	62.0	−2.8	94	16	71	38	6	53	28	54	48	64	5.99	+1.3	13	6,595	s.	29	sw.	29	15	6	10	4.5	0.0	0.0
St. Joseph	967	11	49	28.89	29.92	------	60.8	------	91	16	71	36	6	50	34	53	47	67	4.13	−0.1	10	5,388	nw.	23	nw.	9	16	6	9	4.3	0.0	0.0
Springfield, Mo.	1,324	98	104	28.56	29.96	+.03	59.8	−4.7	90	16	68	38	7	51	28	53	47	67	3.65	−1.5	13	6,826	s.	30	w.	9	18	8	5	3.3	0.0	0.0
Iola	984	11	50	28.90	29.94	+.02	61.3	−3.9	93	16	72	37	7	50	34				3.67	−1.0	9	4,204	s.	19	nw.	10	12	7	12	5.5	0.0	0.0
Topeka	987	92	107				61.0	−3.3	95	16	71	38	20	51	31				2.03	−2.4	9	6,294	nw.	23	nw.	11	16	4	11	4.5	0.0	0.0
Lincoln	1,189	11	81	28.66	29.92	+.01	58.7	−3.0	91	28	70	34	6	48	36	51	45	64	6.41	+2.3	11	7,102	n.	43	sw.	27	11	10	10	5.4	0.0	0.0
Omaha	1,105	115	122	28.76	29.93	+.01	59.8	−2.6	92	17	70	33	6	50	31	50	42	59	3.26	−0.5	10	5,946	nw.	29	nw.	27	16	7	8	4.4	0.0	0.0
Valentine	2,598	47	54	27.25	29.95	+.05	55.2	−1.0	95	23	69	25	21	41	45	46	37	56	1.01	−1.8	6	7,248	n.	32	n.	9	13	9	9	5.1	T.	0.0
Sioux City	1,135	94	164	28.70	29.91	−.01	58.4	−2.0	91	24	70	30	6	47	34	49	40	58	2.71	−1.3	10	8,809	nw.	44	s.	26	11	8	12	5.5	T.	0.0
Huron	1,306	59	74	28.54	29.94	+.02	55.2	−1.2	96	15	68	24	6	42	40	46	37	55	1.85	−1.1	7	7,441	n.	31	s.	23	16	8	7	4.0	0.0	0.0
Pierre	1,572	70	75	28.26	29.91	.00	57.2	−0.8	97	15	70	25	21	44	43	47	37	53	2.11	−0.4	6	7,115	nw.	32	s.	26	11	13	7	4.8	T.	0.0
Yankton	1,233	49	57	28.63	29.94	+.02	58.1	−1.3	91	15	70	29	6	46	41				1.48	−2.4	7	5,862	nw.	30	s.	26	14	10	7	4.3	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1931*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
Northern Slope							**53.6**	**+0.9**										**52**	**1.23**	**−1.2**										**5.5**		
Billings	3,140	5					56.0		95	25	74	21	21	38	54				0.67		6		nw.				9	13	9		0.0	0.0
Havre	2,505	11	67	27.34	29.96	+0.06	56.4	+3.0	95	14	71	31	5	42	48	44	31	46	0.21	−1.8	4	6,242	nw.	35	sw.	16	9	11	11	5.9	T.	0.0
Helena	4,124	89	113	25.80	29.97	+.04	54.0	+2.4	84	13	67	30	21	41	42	42	31	49	1.09	−1.2	10	5,719	sw.	34	sw.	17	4	12	15	6.7	0.8	0.0
Kalispell	2,973	48	56	26.93	29.96	+.08	54.6	+3.2	84	13	68	30	21	42	39	44	34	53	0.52	−0.9	6	4,593	nw.	31	sw.	6	5	12	14	6.3	0.0	0.0
Miles City	2,371	48	55	27.44	29.98	+.07	57.9	+1.2	95	14	72	30	20	44	43	44	30	41	0.59	−1.6	5	4,871	s.	32	nw.	18	12	13	6	4.5	T.	0.0
Rapid City	3,259	50	58	26.58	29.98	+.08	54.8	+0.8	94	25	68	27	21	42	46	45	35	51	1.06	−2.5	8	6,825	n.	37	n.	8	11	14	6	4.8	T.	0.0
Cheyenne	6,088	84	101	24.01	29.96	+.11	48.6	−1.7	82	26	61	22	20	36	44	39	30	54	1.57	−0.9	9	8,266	w.	40	w.	7	6	10	15	6.5	0.1	0.0
Lander	5,372	60	68	24.65	29.98	+.10	51.8	+0.6	83	15	65	28	8	39	47	41	31	54	2.20	−0.1	11	4,231	sw.	36	sw.	26	11	13	7	4.9	0.2	0.0
Sheridan	3,790	10	47	26.10	29.98		52.8		90	25	68	24	20	38	49	43	34	57	2.38	−0.3	9	3,671	nw.	32	nw.	7	6	17	8	5.5	0.6	0.0
Yellowstone Park	6,241	11	48		30.00	+.09	46.4	−1.0	75	25	59	22	8	34	41			55	1.61	−0.6	12	4,835	n.	29	sw.	16	4	13	14		5.5	0.0
North Platte	2,821	11	51	27.03	29.94	+.06	58.1	−0.6	95	15	72	28	20	44	43	48	39	56	0.47	−2.3	6	5,969	nw.	31	nw.	9	13	11	7	4.7	0.0	0.0
Middle Slope							**59.9**	**−2.6**										**60**	**2.59**	**−0.8**										**4.7**		
Denver	5,292	106	113	24.74	29.97	+.13	55.0	−1.2	86	26	66	30	20	43	42	43	33	55	3.45	+1.2	15	5,112	s.	35	n.	5	6	16	9	5.5	7.2	0.0
Pueblo	4,685	80	86	25.29	29.94	+.11	57.9	−1.2	90	15	71	32	22	44	45	45	35	53	2.58	+1.0	10	4,709	nw.	30	w.	3	12	13	6	4.9	T.	0.0
Concordia	1,392	50	58	28.50	29.97	+.06	60.0	−3.2	91	24	70	33	20	50	32	52	47	66	3.83	−0.4	9	5,976	s.	30	nw.	9	13	9	9	4.8	0.0	0.0
Dodge City	2,509	88	100	27.39	29.98	+.11	59.5	−4.0	92	15	71	31	22	48	36	51	45	64	2.14	−0.8	7	9,002	s.	43	nw.	8	18	8	5	3.4	T.	0.0
Wichita	1,358	139	158	28.52	29.94	+.04	61.6	−3.5	91	16	71	38	22	52	29	53	47	62	2.37	−2.1	8	8,375	s.	34	sw.	17	12	11	8	4.9	0.0	0.0
Oklahoma City	1,214	10	47	28.68	29.95	+.06	65.4	−2.3	92	25	75	42	22	56	32	56	50	63	1.18	−3.7	7	6,871	s.	26	n.	8	13	5	13	4.9	0.0	0.0
Southern Slope							**66.7**	**−3.9**										**60**	**2.76**	**+0.1**										**4.4**		
Abilene	1,738	10	52	28.16	29.95	+.08	68.4	−3.6	93	15	80	41	7	57	34	57	49	58	1.14	−2.8	5	6,808	s.	27	sw.	21	10	12	9	5.0	0.0	0.0
Amarillo	3,676	10	49	26.26	29.94	+.10	61.4	−2.7	93	25	73	37	22	49	39	51	44	60	3.11	+0.3	13	6,291	se.	27	w.	4	15	8	8	4.1	0.0	0.0
Del Rio	944	64	71	28.90	29.88	+.01	72.2	−4.8	91	18	82	51	12	62	33	63	58	68	6.10	+3.2	10	5,834	se.	46	w.	4	9	14	8	5.2	0.0	0.0
Roswell	3,566	75	85	26.34	29.90	+.08	65.0	−4.4	93	25	78	43	22	52	39	52	42	52	0.70	−0.4	3	5,422	s.	44	nw.	4	16	13	2	3.3	0.0	0.0
Southern Plateau							**68.2**	**+2.8**										**39**	**0.10**	**−0.3**										**2.0**		
El Paso	3,778	152	175	26.13	29.83	+.05	72.3	+0.8	96	25	85	51	11	59	33	53	34	32	0.06	−0.3	2	6,239	e.	32	nw.	18	22	9	0	2.2	0.0	0.0
Albuquerque	4,972	51	66	25.06	29.85		62.0		86	25	76	38	12	48	36	47	33	44	0.99		5	4,208	sw.	23	se.	30	19	7	5	3.1	0.0	0.0
Santa Fe	7,013	38	53	23.25	29.85	+.04	55.0	−0.7	78	24	68	29	11	42	37	41	27	42	0.46	−0.8	6	4,462	sw.	20	sw.	7	19	9	3	3.3	T.	0.0
Flagstaff	6,907	10	59	23.36	29.86	+.08	51.9	+1.2	80	31	69	26	20	35	44	40		53	0.33		3	5,708	nw.	30	nw.	18	14	13	4		0.0	0.0
Phoenix	1,108	10	107	28.66	29.78	.00	80.5	+5.5	107	31	96	58	20	65	40	57	37	26	T.	−0.1	0	3,886	w.	20	s.	25	29	2	0	1.0	0.0	0.0
Yuma	141	9	54	29.65	29.79	.00	80.8	+4.6	109	31	98	55	20	64	45	60	44	37	0.00	0.0	0	3,207	w.	22	nw.	19	30	1	0	0.2	0.0	0.0
Independence	3,957	6	27	25.92	29.90	+.06	68.7	+5.7	91	17	83	47	14	54	37	51			T.	−0.2	0		s.				19	9	3		0.0	0.0
Middle Plateau							**59.2**	**+3.3**										**38**	**0.52**	**−0.5**										**3.2**		
Reno	4,532	74	81	25.46	29.90	−.01	61.0	+7.4	88	30	77	34	8	45	42	46	34	44	0.72	+0.1	3	4,277	w.	33	w.	13	22	6	3	3.0	0.0	0.0
Tonopah	6,090	12	20				60.4		84	31	71	37	19	50	29	44	28	32	0.10		3		nw.									
Winnemucca	4,344	18	56	25.61	29.96	+.05	58.8	+4.9	90	31	77	29	8	41	49	42	26	36	0.14	−0.7	3	4,809	ne.	28	nw.	7	22	9	0	2.1	0.0	0.0
Modena	5,473	10	43	24.60	29.89	+.07	55.7	+2.2	85	31	73	31	9	39	43	41	25	40	0.72	−0.1	5	7,358	w.	37	n.	2	16	11	4	3.7	0.0	0.0
Salt Lake City	4,360	163	203	25.61	29.94	+.08	59.8	+2.4	89	31	70	36	20	49	35	45	30	37	0.58	−1.3	4	5,376	nw.	30	nw.	7	15	13	3	3.3	0.2	0.0
Grand Junction	4,602	60	68	25.36	29.91	+.08	60.6	−0.5	87	31	74	34	11	47	38	44	28	36	0.44	−0.4	5	4,288	n.	38	nw.	7	15	10	6	3.8	0.0	0.0
Northern Plateau							**60.8**	**+4.2**										**44**	**0.23**	**−1.2**										**4.8**		
Baker	3,471	48	53	26.47	30.04	+.08	54.8	+3.1	87	30	70	28	21	40	43	44	33	50	0.26	−1.3	5	4,268	se.	25	sw.	31	13	11	7	4.7	T.	0.0
Boise	2,739	79	87	27.15	29.98	+.04	61.4	+4.3	92	31	75	32	8	48	38	47	32	40	0.01	−1.4	1	4,258	nw.	24	nw.	31	10	13	8	5.0	0.0	0.0
Lewiston	757	40	48	29.20	30.00	+.04	63.9	+4.4	97	13	78	38	21	50	46				0.36	−1.2	4	2,980	e.	35	nw.	6	9	14	8	5.4	0.0	0.0
Pocatello	4,477	60	68	25.47	29.95	+.06	56.6	+2.8	86	31	70	28	8	44	38	43	30	44	0.36	−1.2	5	5,056	se.	37	sw.	7	12	15	4	4.4	T.	0.0
Spokane	1,929	101	110	27.95	29.98	+.02	60.0	+4.5	93	13	73	36	20	47	41	47	36	48	0.26	−1.2	8	3,941	sw.	23	sw.	6	10	15	6	5.4	0.0	0.0
Walla Walla	991	57	65	28.92	29.98	+.02	64.7	+5.1	95	30	77	42	7	52	38	51	38	42	0.37	−1.2	4	3,051	sw.	24	w.	17	13	14	4	4.3	0.0	0.0
Yakima	1,076	58	67	28.85	30.00		64.3	+5.3	95	30	78	39	17	51	42	49	34	38	T.	−0.6	0	4,740	nw.	27	nw.	6	14	13	4	4.2	0.0	0.0
North Pacific Coast Region							**57.7**	**+4.0**										**68**	**0.95**	**−1.3**										**5.2**		
North Head	211	11	56	29.88	30.11	+.08	53.7	+2.8	85	10	58	45	15	49	28	49	47	82	1.32	−1.6	9	10,661	n.	39	nw.	6	8	16	7	5.2	0.0	0.0
Port Angeles	29	8	53		30.10		53.3		79	30	62	40	9	45	30				0.62	−0.6	7	5,252	sw.	28	nw.	6	10	14	7		0.0	0.0
Seattle	125	215	250	29.93	30.06	+.05	58.5	+4.0	85	10	68	41	7	50	32	50	42	60	1.02	−0.8	8	5,070	ne.	34	sw.	16	12	12	7	5.0	0.0	0.0
Tacoma	194	172	201	29.86	30.06	+.04	58.0	+3.9	84	10	68	42	20	49	38				1.04	−1.1	6	5,655	n.	38	sw.	6	7	19	5	5.3	0.0	0.0
Tatoosh Island	86	9	53	29.99	30.09	+.08	52.2	+2.6	65	10	56	45	16	48	14	49	47	86	1.46	−2.5	9	7,388	w.	43	e.	21	5	8	18	7.1	0.0	0.0
Medford	1,329	29	58	28.58	29.98		63.6		98	29	81	35	18	46	49	52	42	56	0.23	−1.0	4		nw.	28	nw.	7	13	11	7	4.6	0.0	0.0
Portland, Oreg.	153	68	106	29.89	30.05	+.02	62.7	+5.8	93	30	74	40	8	52	34	53	45	59	1.09	−1.1	8	3,807	nw.	18	w.	16	9	10	12	5.7	0.0	0.0
Roseburg	510	75	99	29.50	30.04	+.01	61.2	+5.2	94	10	75	37	18	47	48	52	44	62	0.56	−1.4	5	2,833	n.	19	sw.	13	16	11	4	3.7	0.0	0.0
Middle Pacific Coast Region							**65.2**	**+5.4**										**63**	**0.87**	**−0.1**										**3.8**		
Eureka	62	73	89	29.99	30.06	+.01	54.5	+2.5	67	24	59	44	8	50	21	51	49	84	0.49	−1.3	6	4,861	n.	32	n.	18	11	5	15	6.0	0.0	0.0
Red Bluff	330	5	58	29.55	29.90	−.05	74.4	+8.1	101	29	88	54	22	60	38	58	43	40	1.00	−0.1	3	4,928	nw.	24	nw.	18	21	4	6	3.1	0.0	0.0
Sacramento	69	106	117	29.82	29.89	−.05	69.6	+6.3	98	29	84	50	6	55	39	57	48	56	0.67	−0.1	3	6,384	s.	31	nw.	18	25	4	2	1.6	0.0	0.0
San Francisco	155	208	243	29.78	29.94	−.05	61.8	+5.0	90	19	70	50	5	54	34	54	50	72	1.10	+0.3	2	5,376	sw.	29	n.	19	11	14	6	4.8	0.0	0.0
San Jose	141	12	110	29.79	29.94		65.9	+5.2	95	9	78	45	7	54	41				1.08	+0.6	1	4,552	nw.	28	sw.	23	16	12	3	3.5	0.0	0.0
South Pacific Coast Region							**69.1**	**+5.7**										**67**	**0.66**	**+0.3**										**4.2**		
Fresno	327	89	98	29.53	29.88	−.04	73.6	+6.5	100	29	89	52	25	58	35	58	45	45	1.22	+0.8	2	5,002	nw.	27	nw.	13	20	7	4	2.8	0.0	0.0
Los Angeles	338	159	191	29.58	29.94	−.01	67.5	+5.3	87	19	75	55	22	60	27	60	56	74	0.52	+0.1	2	3,005	sw.	12	w.	28	10	17	4	4.5	0.0	0.0
San Diego	87	62	70	29.84	29.93	−.02	66.2	+5.4	77	24	71	58	22	61	17	61	59	82	0.24	−0.1	3	4,130	w.	16	w.	30	9	16	6	5.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.84	29.92		81.4	+2.8	92	15	87	73	2	76	16				7.46	+2.2	18	6,296	e.	28	e.	2	4	19	8	6.2	0.0	0.0
Panama Canal																																
Balboa Heights	118	6	97																													
Cristobal	36	6	97																													
Alaska																																
Fairbanks	455	11	44		[1]29.88		40.8		67	19	50	17	3	32	31			60	0.68		13	4,334	ne.	21	e.	1	5	10	16		2.0	0.0
Juneau	80	11	50	[1]29.88	[1]29.97		46.0		68	21	51	37	13	41	28	43	39	78	8.55		25	4,612	s.	26	se.	11	1	4	26	8.9	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]30.00	[1]30.03		74.8	0.0	82	28	80	67	18	70	12	68	65	73	3.12	+1.4	6	5,695	ne.	25	e.	4	12	15	4	4.3	0.0	0.0

[1] Observations taken hourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, May, 1931*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				40.5		46.1	34.9	68	28	5.40		0.0
Sydney, C. B. I	48	29.92	29.97	0.00	50.4	+5.2	60.6	40.3	83	30	3.62	−0.15	0.0
Halifax, N. S	88	29.86	29.97	−.01	52.0	+3.6	61.6	42.4	82	32	3.54	−0.72	0.0
Yarmouth, N. S	65	29.84	29.91	−.07	49.8	+2.2	57.0	42.6	71	35	4.63	+1.06	0.0
Charlottetown, P. E. I	38	29.84	29.88	−.08	50.0	+3.1	58.0	42.0	76	33	1.12	−1.79	0.0
Chatham, N. B	28	29.81	29.84	−.11	49.3	+0.8	60.9	37.7	79	26	2.05	−1.16	0.0
Father Point, Que	20												
Quebec, Que	296	29.58	29.90	−.04	53.1	+3.2	63.1	43.2	82	29	4.19	+1.11	T.
Doucet, Que	1,236				48.7		60.0	37.5	86	20	2.72		1.0
Montreal, Que	187	29.66	29.87	−.07	57.1	+2.4	66.5	47.8	87	33	2.74	−0.21	0.0
Ottawa, Ont	236	29.61	29.86	−.08	56.6	+1.7	67.6	45.7	89	27	1.85	−0.74	0.0
Kingston, Ont	285	29.58	29.89	−.07	53.6	+0.7	61.0	46.3	78	30	4.28	+1.60	0.0
Toronto, Ont	379	29.50	29.90	−.08	55.9	+2.7	65.9	45.9	84	30	1.89	−1.15	0.0
Cochrane, Ont	930				48.0		59.5	36.5	89	22	2.28		T.
White River, Ont	1,244	28.56	29.88	−.07	45.7	0.0	58.6	32.8	78	18	2.25	+0.30	2.5
London, Ont	808				55.4		67.0	43.9	87	27	2.30		0.0
Southampton, Ont	656	29.20	29.92	−.04	52.2	+1.5	61.9	42.5	86	29	2.54	+0.10	0.0
Parry Sound, Ont	688	29.20	29.90	−.05	53.8	+2.7	63.8	43.8	81	30	1.88	−1.05	0.0
Port Arthur, Ont	644	29.18	29.89	−.07	47.9	+2.0	58.0	37.8	90	29	2.84	+0.69	T.
Winnipeg, Man	760	29.10	29.93	−.03	50.0	−1.6	61.0	39.0	90	16	2.43	+0.15	12.8
Minnedosa, Man	1,690	28.12	29.93	−.03	49.6	+1.2	64.0	35.2	91	15	0.10	−1.35	T.
Le Pas, Man	860				45.8		56.8	34.9	83	18	1.01		0.5
Qu'Appelle, Sask	2,115	27.66	29.90	−.04	50.8	+1.0	66.4	35.2	95	16	0.40	−1.25	0.8
Moose Jaw, Sask	1,759				55.0		71.9	38.1	96	17	0.45		1.0
Swift Current, Sask	2,392	27.38	29.88	−.04	55.0	+4.3	71.3	38.7	94	26	0.66	−1.10	0.0
Medicine Hat, Alb		27.44			54.7	+0.6	68.7	40.8	90	28	0.73	−0.58	0.1
Calgary, Alb	3,428	26.26	29.80	−.08	49.8	+0.8	62.5	37.2	82	24	0.56	−1.21	3.0
Banff, Alb	4,521	25.35	29.90	+.02	46.8	−0.2	59.6	33.9	78	25	2.02	−0.02	9.0
Prince Albert, Sask	1,450	28.37	29.94	−.01	50.5	+2.9	64.8	36.2	89	13	0.63	−0.63	1.7
Battleford, Sask	1,592	28.17	29.90	−.02	52.5	+1.5	67.9	37.2	89	25	0.12	−1.50	T.
Edmonton, Alb	2,150	27.59	29.86	−.02	51.9	+1.1	64.8	39.0	81	28	1.80	+0.25	1.7
Kamloops, B. C	1,262												
Victoria, B. C	230	29.81	30.07	+.07	55.4	+2.9	62.9	48.0	78	43	1.48	.00	0.0
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151	29.93	30.09	+.03	71.7	+2.3	77.2	66.2	80	61	5.09	+0.43	0.0

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Kingston, Ont	285	29.67	29.99	−.03	44.4	+4.4	52.1	36.7	72	26	2.77	+0.98	3.0
White River, Ont	1,244	28.65	29.99	−.05	32.6	−0.4	45.6	19.7	67	−2	2.81	+0.56	13.6
London, Ont	808				44.7		55.7	33.7	78	25	3.54		4.6
Medicine Hat, Alb		27.47			45.1	+0.6	59.4	30.8	78	13	0.15	−0.59	0.2
Calgary, Alb	3,428	26.40	30.00	+.10	40.2	+0.6	53.9	26.5	78	13	1.11	+0.47	11.1
Banff, Alb	4,521	25.36	29.96	+.06	38.2	+2.9	48.9	27.4	72	15	1.78	+0.70	16.1
Edmonton, Alb	2,150	27.62	29.91	+.02	43.9	+4.0	56.8	31.0	80	13	0.45	−0.43	4.2
Kamloops, B. C	1,262	28.72	30.02	+.09	51.5	+2.6	62.8	40.3	82	29	0.17	−0.22	T.
Estevan Point, B. C	20				46.8		54.0	39.6	68	30	8.51		0.0
Prince Rupert, B. C	170				45.6		52.7	38.5	70	32	10.73		0.0
Hamilton, Ber	151	30.01	30.17	+.12	66.3	+2.4	71.7	60.9	77	58	0.73	−3.45	0.0

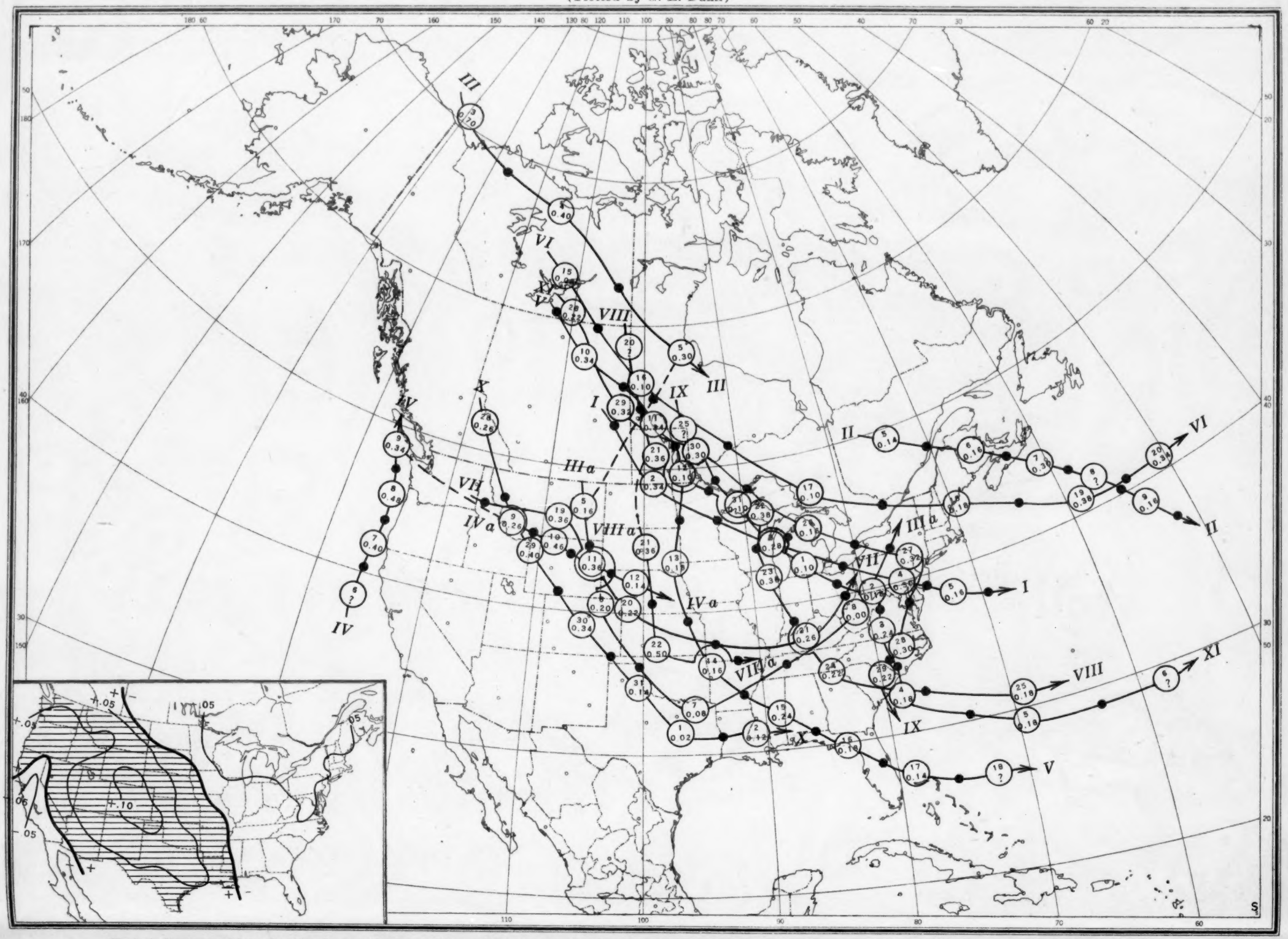
Chart I. Departure (°F.) of the Mean Temperature from the Normal, May, 1931

Chart I. Departure (°F.) of the Mean Temperature from the Normal, May, 1931

4 a.m.
5 a.m.
6 a.m.
7 a.m.
8 a.m.
9 a.m.
Barkerville
Edmonton
The Pas
Prince Albert
Calgary
Medicine Hat
Qu'Appelle
Swift Current
Minnedosa
Winnipeg
White River
Cochrane
Father Point
Quebec
Devils Lake
Bismarck
Minneapolis
St. Paul
Pierre
Huron
Rapid City
Green Bay
La Crosse
Madison
Milwaukee
Chicago
Dubuque
Charles City
Yankton
Sioux City
Omaha
Des Moines
Davenport
Peoria
La Salle
Fort Wayne
Detroit
Cleveland
Toledo
Sandusky
Buffalo
Toronto
Rochester
Albany
Boston
Portland
Sandy Hook
Atlantic City
Cape May
Pittsburgh
Harrisburg
Philadelphia
Baltimore
Washington
Columbus
Indianapolis
Cincinnati
Terre Haute
Springfield
Kansas City
Topeka
St. Joseph
Concordia
Hannibal
St. Louis
Louisville
Lexington
Evansville
Parkersburg
Mount Weather
Elkins
Staunton
Richmond
Lynchburg
Norfolk
Cape Henry
Manteo
Hatteras
Raleigh
Wytheville
Knoxville
Asheville
Charlotte
Nashville
Memphis
Chattanooga
Corinth
Little Rock
Fort Smith
Muskogee
Oklahoma
Springfield
Bentonville
Wichita
Dodge City
Iola
Lincoln
Omaha
North Platte
Cheyenne
Denver
Leadville
Canon City
Pueblo
Durango
Albuquerque
Santa Fe
Amarillo
Altus
Roswell
Abilene
Fort Worth
Dallas
Shreveport
Vicksburg
Meridian
Jackson
Montgomery
Macon
Savannah
Charleston
Columbia
Wilmington
Augusta
Atlanta
Anniston
Birmingham
Palestine
Mobile
Pensacola
Thomasville
Jacksonville
Apalachicola
Tallahassee
Tampa
Key West
Miami
Nassau
Bermuda
Havana
Cienfuegos
Santiago de Cuba
Prince
Taylor
Houston
Galveston
New Orleans
Burrwood
Del Rio
San Antonio
Corpus Christi
Brownsville
El Paso
Tucson
Phoenix
Yuma
San Diego
Los Angeles
San Francisco
Fresno
Tonopah
Independence
Modoc
Red Bluff
Winnemucca
Reno
Salt Lake City
Grand Junction
Pocatello
Helena
Havre
Miles City
Billings
Sheridan
Moorhead
Devils Lake
Williston
Minot
Grand Forks
Bismarck
Jamestown
Valley City
Fargo
Aberdeen
Watertown
Redfield
Pierre
Rapid City
Huron
Mitchell
Yankton
Sioux City
Norfolk
Lincoln
Grand Island
North Platte
Omaha
Des Moines
Cheyenne
Laramie
Rawlins
Lander
Casper
Sheridan
Billings
Miles City
Glasgow
Havre
Helena
Butte
Missoula
Kalispell
Spokane
Walla Walla
Pendleton
Baker
Boise
Pocatello
Idaho Falls
Blackfoot
Malad City
Logan
Salt Lake City
Grand Junction
Montrose
Durango
Pueblo
Colorado Springs
Denver
Leadville
Canon City
Trinidad
Raton
Santa Fe
Albuquerque
Gallup
Flagstaff
Winslow
Prescott
Phoenix
Yuma
Tucson
Roswell
Amarillo
Altus
Wichita
Dodge City
Iola
Topeka
Kansas City
St. Joseph
Concordia
Hannibal
Springfield
Bentonville
Muskogee
Fort Smith
Oklahoma
Little Rock
Memphis
Corinth
Chattanooga
Knoxville
Asheville
Charlotte
Nashville
Evansville
Louisville
Lexington
Cincinnati
Indianapolis
Terre Haute
Springfield
Peoria
Davenport
Fort Wayne
Toledo
Cleveland
Sandusky
Buffalo
Rochester
Albany
Syracuse
Binghamton
Scranton
New York
Boston
Portland
Sandy Hook
Atlantic City
Cape May
Pittsburgh
Harrisburg
Philadelphia
Baltimore
Washington
Columbus
Parkersburg
Mount Weather
Elkins
Staunton
Richmond
Lynchburg
Norfolk
Cape Henry
Manteo
Hatteras
Raleigh
Wytheville
Knoxville
Asheville
Charlotte
Nashville
Memphis
Chattanooga
Corinth
Little Rock
Fort Smith
Muskogee
Oklahoma
Springfield
Bentonville
Wichita
Dodge City
Iola
Lincoln
Omaha
North Platte
Cheyenne
Denver
Leadville
Canon City
Pueblo
Durango
Albuquerque
Santa Fe
Amarillo
Altus
Roswell
Abilene
Fort Worth
Dallas
Shreveport
Vicksburg
Meridian
Jackson
Montgomery
Macon
Savannah
Charleston
Columbia
Wilmington
Augusta
Atlanta
Anniston
Birmingham
Palestine
Mobile
Pensacola
Thomasville
Jacksonville
Apalachicola
Tallahassee
Tampa
Key West
Miami
Nassau
Bermuda
Havana
Cienfuegos
Santiago de Cuba
Prince
Taylor
Houston
Galveston
New Orleans
Burrwood
Del Rio
San Antonio
Corpus Christi
Brownsville
El Paso
Tucson
Phoenix
Yuma
San Diego
Los Angeles
San Francisco
Fresno
Tonopah
Independence
Modoc
Red Bluff
Winnemucca
Reno
Salt Lake City
Grand Junction
Pocatello
Helena
Havre
Miles City
Billings
Sheridan
+6°
+8°
+4°
+4°
+2°
+2°
+2

Chart II. Tracks of Centers of Anticyclones, May, 1931. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by G. E. Dunn)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

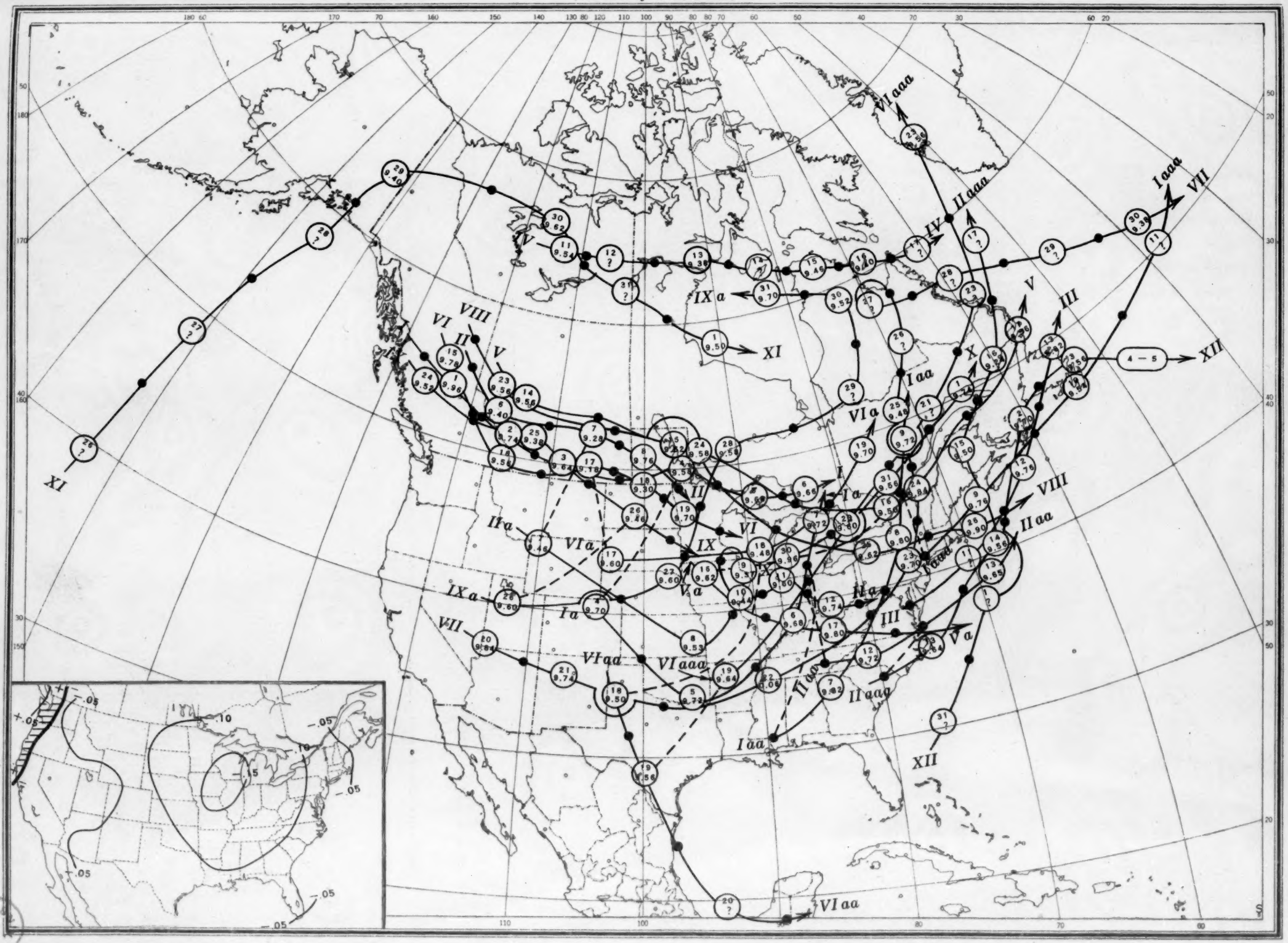
Chart III. Tracks of Centers of Cyclones, May, 1931. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by G. E. Dunn)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

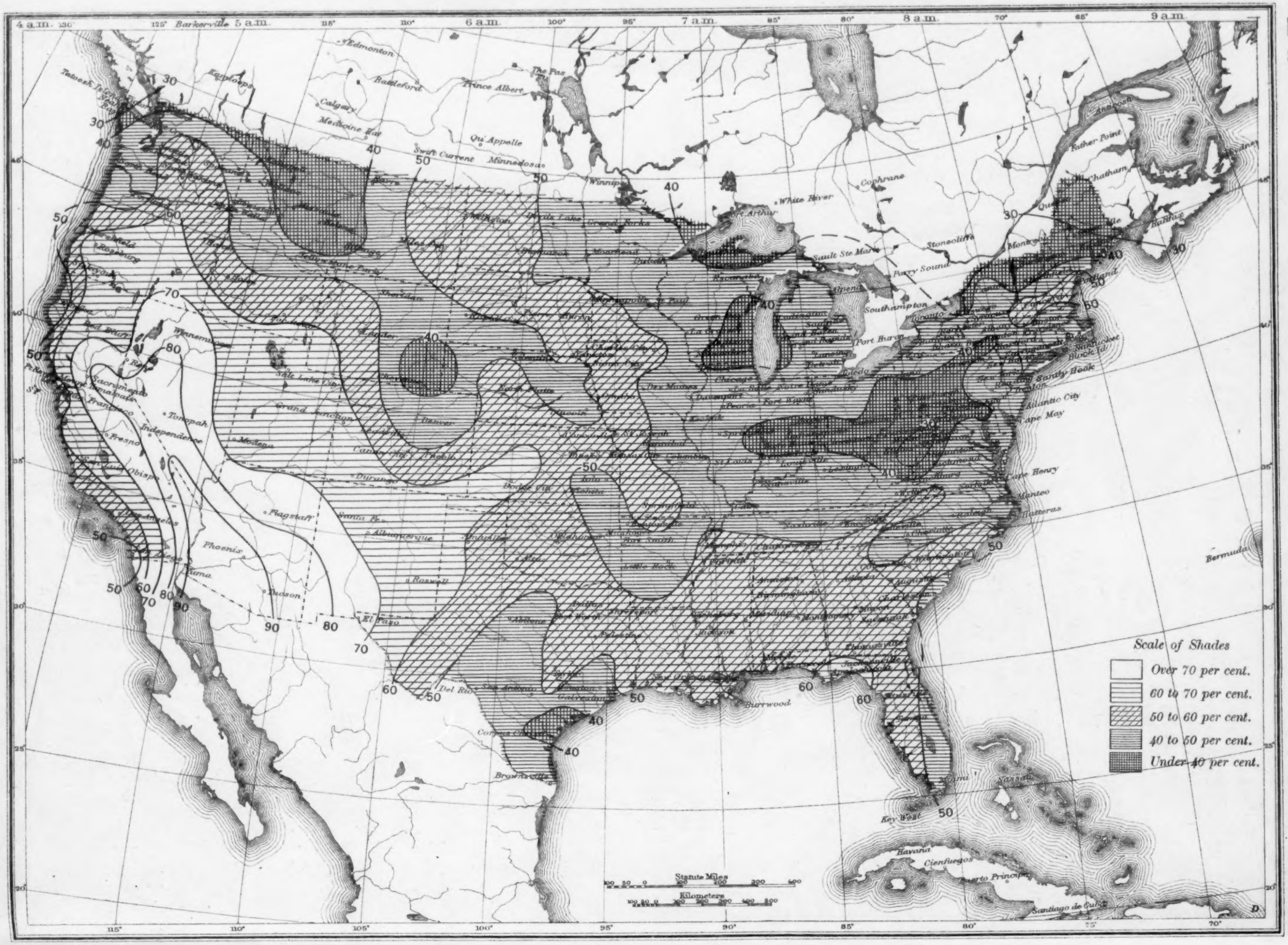
Chart III. Tracks of Centers of Cyclones, May, 1931. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by G. E. Dunn)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, May, 1931



May, 1931. M. W. R.

Chart V. Total Precipitation, Inches, May, 1931. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, May, 1931. (Inset) **Departure of Precipitation from Normal**

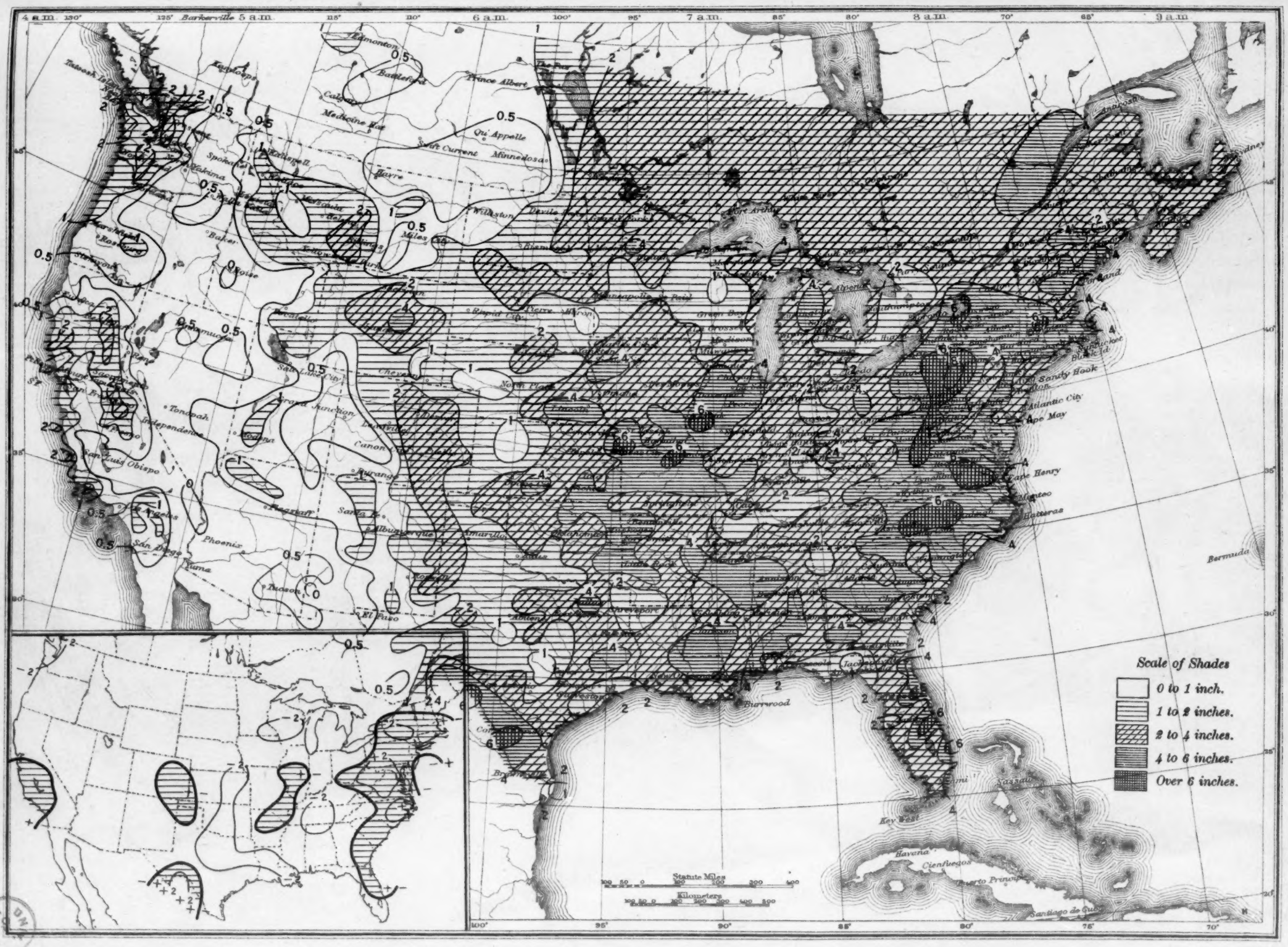


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, May, 1931

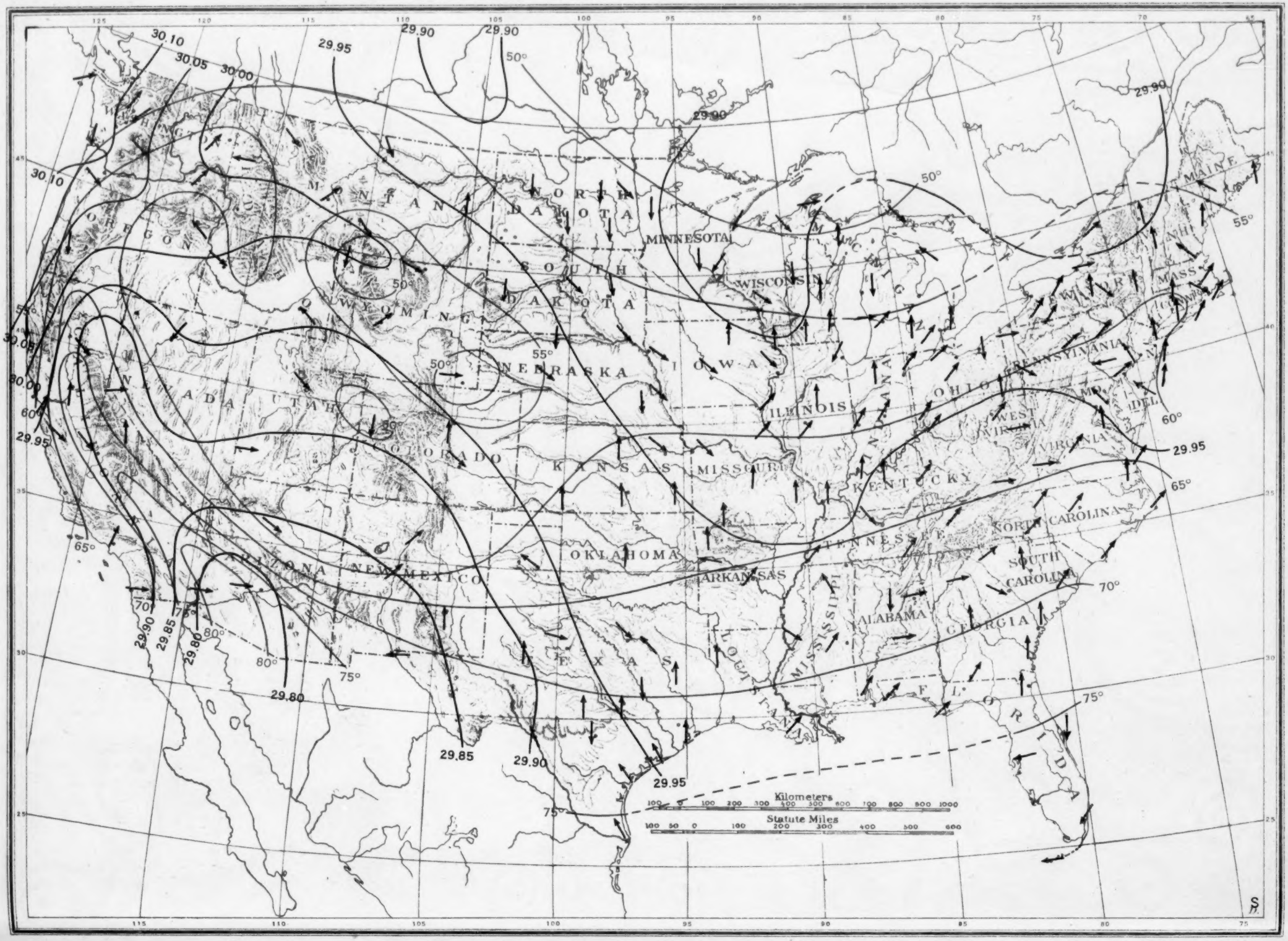


Chart VIII. Weather Map of North Atlantic Ocean, May 5, 1931

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, May 5, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart IX. Weather Map of North Atlantic Ocean, May 6, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

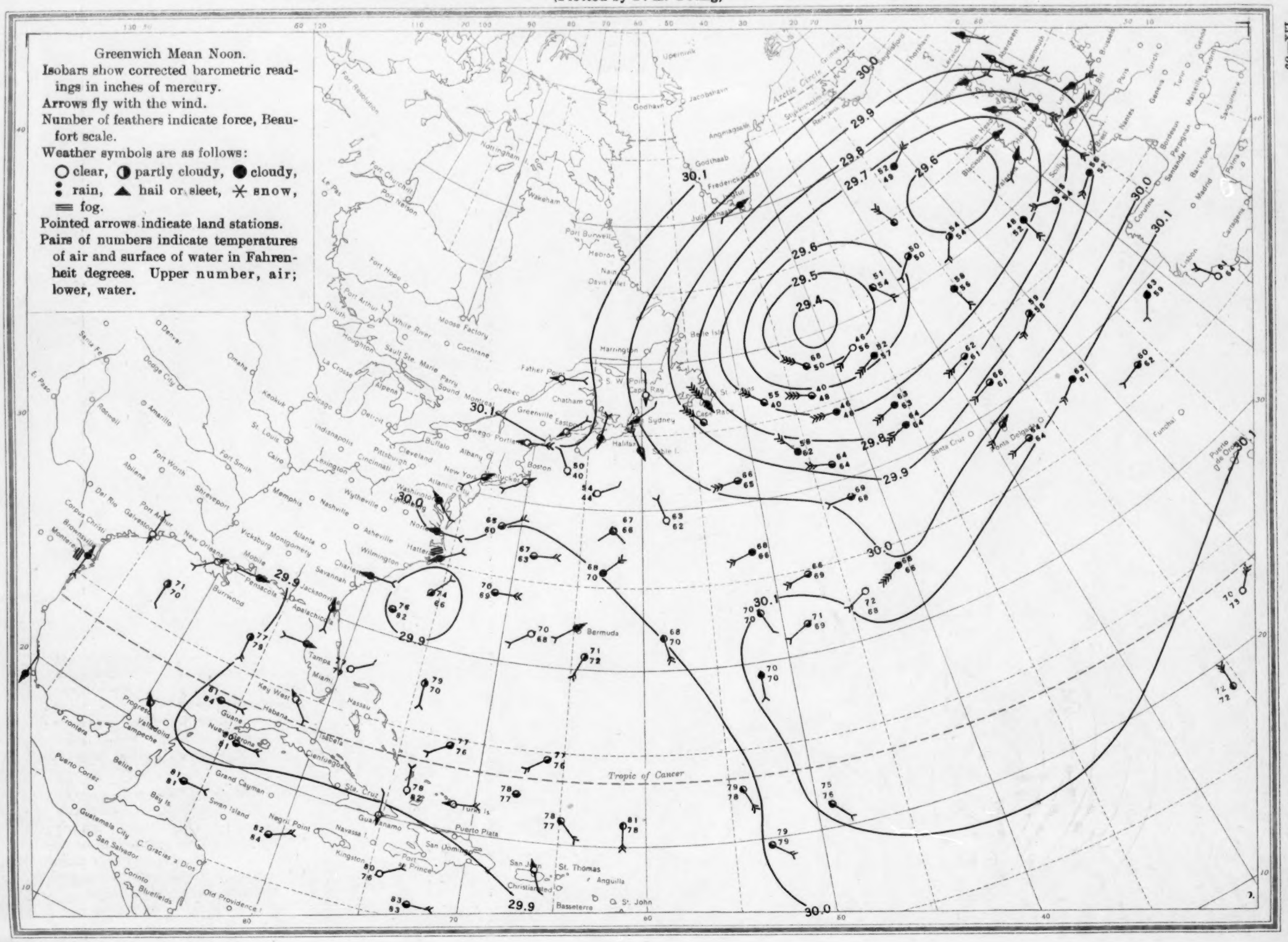


Chart X. Weather Map of North Atlantic Ocean, May 7, 1931

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, May 7, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ═ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

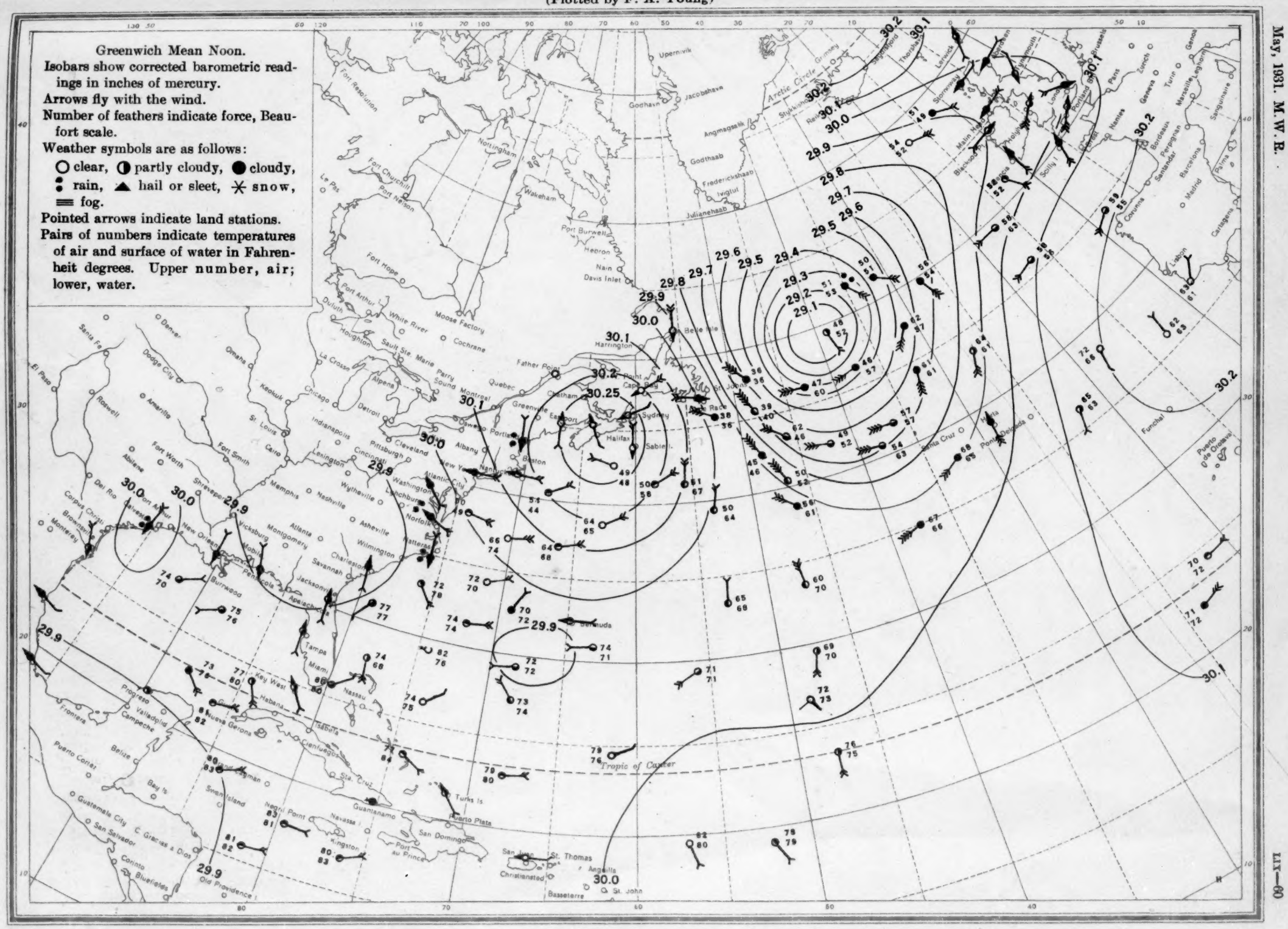


Chart XI. Weather Map of North Atlantic Ocean, May 8, 1931

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.